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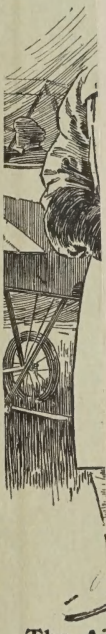

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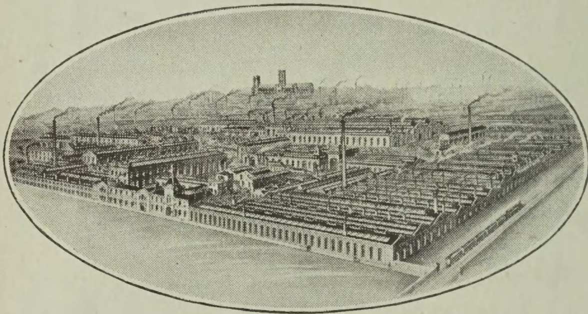

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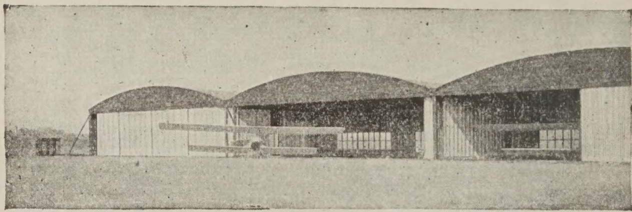

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The Aviation Pocket-Book

for 1916

BY

R. BORLASE MATTHEWS

ASSOCIATE MEMBER OF THE INSTITUTION OF CIVIL ENGINEERS
MEMBER OF THE INSTITUTION OF ELECTRICAL ENGINEERS
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PREFACE TO THE FIRST EDITION

Thanks to the courtesy of Count Henri de la Vaulx, Member of the Official French Aero Commission and, for many years, holder of the world's record for long distance ballooning, the Author was privileged to be present on the memorable occasion when the late Wilbur Wright, for the first time in history, flew with a passenger for over an hour in an aeroplane. This feat was accomplished as recently as 1908, and the great progress that has been made since is very remarkable. The Royal Aero Club alone has granted about 300 pilots' certificates, and this is a very small number compared with the certificates issued abroad.

When examining Wilbur Wright's biplane—then the only really successful flying machine in the world—it was brought home to the Author that it represented certain principles of construction which were arrived at as the result of elimination by trial and error, and with the aid of mathematical research. This was further emphasised by observations made as the result of attendance at the world's first aviation meeting at Rheims, and the first aero exhibition at Paris; and thus led to a collection of data which would enable an analysis of the principle to be made.

Such information undoubtedly being of great value and assistance to all interested in the art and principles of aviation, it was arranged in the present form of a pocket-book. Owing to the rapid advance of the art, it was naturally difficult to select the most useful matter out of the very considerable mass of data which has accumulated; however, the choice has been carefully made. The Author has avoided, as much as possible, the introduction of mathematical matter, and also any information contained in other pocket-books, so that this little volume should

379960

serve as a companion or supplement to standard mechanical engineering books of reference.

Originally it was the intention of Mr W. B. Esson, M.I.C.E., M.I.E.E., past President of the Society of Civil and Mechanical Engineers, to collaborate with the Author, and the manuscript was commenced jointly, but pressure of work prevented this arrangement from being carried through. The Author owes his thanks to Mr Esson for valuable assistance and advice. He also has to acknowledge the services of his assistant, Mr L. Preston Parker, B.Sc., Wh.Ex., whose experience as a demonstrator in aviation experimental classwork, as well as his general scientific training, has been of considerable help in the preparation of the book.

R. BORLASE MATTHEWS.

SWANSEA, 1913.

PREFACE TO THE FOURTH EDITION

WAR has proved a blessing in disguise, as far as the development of the Art of Aviation is concerned. The progress made since that fatal fourth day of August 1914 is stupendous, and can only be fully appreciated by those who are in the position to be acquainted with the details. The Royal Aero Club has now issued over 2,350 pilots' certificates, and a vast army of workmen are to-day employed in aeroplane manufacture. So when days of peace return, the aeroplane will occupy a very different position in the world compared with the pre-war period, and one which will benefit all mankind.

Incidentally, increased interest in aviation has resulted in a demand necessitating a new and fourth edition of this Aviation Pocket-Book.

R. BORLASE MATTHEWS.

5 GLOUCESTER PLACE,
SWANSEA, *February* 1916.

CONTENTS

A REVIEW OF AVIATION DEVELOPMENTS

ALREADY the duration of the Great War has been sufficient to so thoroughly and severely test the aeroplane that very great modifications have been made in the details of its design and construction. Developments have been successfully carried out which, in times of peace, could only have been the work of many years. As compared with the pre-war period, the aeroplane is now a very practical piece of apparatus, with much inherent stability, and also a machine that will withstand considerable mishandling and rough usage.

Military requirements very wisely prohibit the publication of much information which would otherwise be of very great interest to all who follow closely the progress of the art of aviation. However, some general particulars can be disclosed without any objection. As an indication of the immense size of some of the latest aeroplanes, it may be mentioned that individual engines up to 300 horse-power are to-day being manufactured as a standard; also that two or more engines are commonly employed on the bigger and heavier aeroplanes. On one American seaplane, now under construction, the horse-power of the engines will total 1,000. These powerful engines are needed, not only on account of the necessity for speed and climbing powers, but also because of the fact that the armament is increasing in size and weight; in fact even armour is being added.

Apparently the enemy has been left far behind in this particular development. It is true, rumours are occasionally heard of large German machines for offensive and defensive purposes, but none have as yet materialised. Recently a small scare has been raised by a section of the more sensational newspapers with lurid descriptions of the offensive possibilities of the German Fokker aeroplane. A captured example of one of the earlier types of this machine was on view at Whitehall as long ago as November last, so anyone could then have examined the machine at close quarters, if they so desired. Inquiry from any aviation expert would have made it clear that this particular make of aeroplane is really an inferior copy of the French Morane-Saulnier avion. The machine has naturally been much developed since, and the latest pattern Fokkers are equipped with engines of about double the horse-power they had at the beginning of the war, *i.e.*, the increase is from 80 to about 160 h.p. This considerably improves the machine for scouting purposes, for which use alone it is suitable. Much has been made of the fact that this particular type of monoplane is

fitted with a gun that shoots through the propeller. It is an open secret that firing between the blades of the propeller has been in use by the Allies for over a year. In fact many machines have been built in England with propellers fitted with deflectors for warding off any bullets that happen to be fired at a moment when they would not pass between the individual revolving blades. All reports at present indicate that the aeroplanes of the Allies are ahead, and well ahead, of the German machines; they are faster, can climb quicker, and be more easily manœuvred. It is true that the German machines have been wonderfully improved, but also it must be borne in mind that the Allies are by no means idle or infertile of invention. It must also be remembered that so far, for every advance in aeroplane design and piloting by the enemy, the Allies have been able to advance one step further and out-class them, so there seems to be no reason why this superiority should not be maintained in the future. It will be noted that practically all the fighting in the air is done over and behind the German lines, indicating greater aggression and power on the part of the Allies. Though Germany possessed about 1,250 aeroplanes at the outset of the war and has constructed large numbers since, it is well known that the Allies have several aeroplanes to each one owned by the enemy, and have thus made a considerable step towards the attainment of the "command of the air," a phrase that will doubtless one day have as real and as far-reaching a significance as is now attached to the "command of the sea." So great has been the progress of aviation, and so forcibly has its vital importance been demonstrated, that if ever another war should trouble the world, it seems more than probable that it will be fought in the air. On land the enemy can dig himself safely into the ground, out of reach of high-explosive shells. His ships may be driven off the seas but, thanks to his mines and submarines, he can safely hide in harbour. Hence the mode of successful attack for the future will have to be in the air. It will probably not be many years now before every nation will have and will rely upon large air fleets for offensive and defensive purposes.

The fact that war is a very uncommercial proposition is being brought home to many civilian engineers. Specifications are drawn up apparently regardless of cost, so long as the qualities of reliability and effectiveness are obtained. This expensive side of construction has its advantage notwithstanding, for invaluable data concerning the properties of materials is by this means accumulated, which will be of the utmost importance in days of peace. It, however, gives an engineer food for thought when he sees the waste of labour and machining in such operations as the turning of pistons and cylinders out of solid bars of steel.

Engine speeds have been gradually rising, until the modern aeroplane engine regularly operates at a speed (1,000 to 2,500 r.p.m.) far in excess of efficient propeller speed (700 to 1,200 r.p.m.), so

that reduction gears have now to be incorporated. Electric engine starters and dynamos for wireless telegraphic apparatus are now also regularly installed on the larger machines. Further, as the radius of operation extends, more and more fuel and oil has to be stored. Thus it will be readily appreciated that the dead-weight to be carried by a modern military aeroplane is considerably increasing.

Air-cooled engines seem to have been almost given up for the present, as military requirements, in most instances, call for machines that will remain in the air for at least three to four hours at a time. This necessitates provision for carrying a considerable quantity of fuel and lubricating oil, hence engine efficiency is of supreme importance, and so the heavier, but more economical, water-cooled engine has become the standard. At the same time there is probably nothing that can compete with such an air-cooled engine as the Gnome for purposes of short distance speed records and climbing competitions.

With the exception perhaps of the United States, there is not at present a commercial market for aeroplanes, and such a demand seems likely to appear but slowly during the next few years, though it must come ultimately. Present experience indicates the possibility of the use of a thirty horse-power engine for ordinary private flying machines, capable of doing about sixty miles per hour. Of course military machines utilise engines far in excess of this, but large engines are too expensive to operate for any but the most fortune-favoured amateur aviators, so it is a happy thing that there is a possibility of successfully utilising comparatively low powers.

The British aeronautical service is of course fortunate, not only in equipment, but in personnel, and has probably the most consistently good pilots of any nation concerned. The reason for this must be sought for, not only in the men themselves and their highly specialised training, but also in the uncertain climate in which they have learned, and have been accustomed to fly. "British pilots had on every occasion proved themselves superior to the Germans," so said Mr Tennant, the Under Secretary for War, in the course of his speech in February 1915. The following extract from the same speech is also of special interest :—

"In regard to flying, the British design of aeroplane had been proved to be superior to that of any other nation. The British aeroplane lasted about twice as long as those of other Powers. British made engines were now in use, and we were actually becoming self-supporting in regard to all aeronautical materials. Both the motor trade and the shipbuilding trade were now engaged in manufacturing aeroplanes."

As an indication of the very extensive use of aeroplanes at the front, the official report issued early in October 1914, is specially à propos. The report stated that up to 21st September the air mileage made by our airmen since the beginning of the War amounted to 87,000 miles, an average of 2,000 miles per day.

The total time spent in the air was 1,400 hours. Of course, many more machines are now in use notwithstanding wear, tear, and wastage—so these figures will be very considerably exceeded at the present time.

Sir John French says that as regards the use to which aeroplanes are being put in war, almost every day new methods for employing them, both strategically and tactically, are discovered and put into practice. Besides reconnaissance, and bomb dropping on railways, airship stations, and buildings, the use of aeroplanes for tactical operations against troops is also growing. For this purpose special bombs, machine guns, and arrows are now in use.

On page xiii will be found some of the more important achievements of the Allied aeroplane services. Especially memorable is the wonderful and dramatic feat of Lieut. Warneford, V.C., in destroying a Zeppelin in mid-air, near Ghent. Also specially noteworthy is the effective aid rendered by aeroplanes in the destruction of the "Königsberg" on 6th July 1915. Without the assistance of aeroplanes it seems probable that the "Königsberg" would have held out for a very considerable length of time. In the course of these operations a total time was spent in the air of thirteen hours, and a distance traversed of 960 miles, under most trying circumstances of extremes of temperatures and big air pockets, which latter were sometimes as much as 250 feet deep.

As regards lighter-than-air varieties of air-craft, little is available for publication. The piratical raids by Zeppelins have demonstrated the possibility of travelling long distances, but the results achieved by this particular mode of adventure have been negligible from a military point of view. These exploits have more or less drawn public attention away from the use of these airships in their proper sphere, where they have proved their use and value to such an extent that they will undoubtedly be retained in the future for special military work. At their best these craft are very vulnerable. The Germans alone, as far as can be gathered from available records, have lost over eighteen Zeppelins and ten other airships.

In conclusion, it may be well to point out that although the attention of every one concerned and interested in the development of aviation may now appear to be too exclusively devoted to military purposes, it is because the very best aeronautical equipment is vital to the combatants. Knowledge is thereby very greatly advancing, and inquiry is being quickened in every branch of the subject. Hence, owing to this urgent concentration of time and money, results beneficial to the whole world are being obtained, which under circumstances of peace would only be the accomplishment of many years.

SOME NOTABLE ALLIED AEROPLANE WAR ACHIEVEMENTS

1914.

Sept. 23.—Düsseldorf: Zeppelin hangar damaged by five aeroplanes.

Oct. 9.—Düsseldorf: Zeppelin airship destroyed by three aeroplanes.

Nov. 21.—Friedrichshafen: Zeppelin factory severely damaged by three planes.

Dec. 4 and 9.—Freiburg-im-Breisgau attacked.

Dec. 24.—Brussels: Parseval airship and hangar destroyed.

" 25.—Cuxhaven: Bombs dropped on naval station and gas works.

" 24 and 26.—Metz: Attacked by French aeroplanes.

1915.

Jan. 25.—Zeebrugge: Two submarines badly damaged.

Feb. 11.—Coast of Belgium: Concerted raid by a flight of thirty-four aeroplanes, which effected considerable damage on military works.

" 16.—Coast of Belgium: Raid by forty aeroplanes, military works again damaged.

Mar. 9.—Ostend: Attacked by six aeroplanes.

" 24.—Antwerp: Submarines bombed by five aeroplanes.

" 26.—Metz: Attacked by ten avions.

April 16.—El Sirr, Suez Canal: Bombs dropped by three aeroplanes.

" 19.—Gontrode: Zeppelin hangar damaged.

May 27.—Ludwigshafen: Attacked by eighteen aeroplanes.

June 3.—German Staff Headquarters: Attacked by twenty-nine avions.

" 7.—Near Ghent: Zeppelin destroyed in mid-air by Lieut. Warneford.

" 15.—Karlsruhe: Attacked by twenty-three avions.

July 6.—Cruiser "Königsberg": Destroyed by monitors, with the aid of two aeroplanes.

" 16.—Chauny: Attacked by ten avions.

July 20.—Conflans: Bombed by thirty-one avions.
,, 22.—Conflans: Again attacked by a large squadron.
,, 26.—Nantillois: Attacked by a large squadron.
,, 30.—Pechelbronn: Attacked by forty-five avions.
,, 30.—Freiburg: Bombed by a squadron.
Aug. 20.—Off Ostend: First submarine sunk by aeroplane.
,, —In Dardanelles: First transport sunk by aeroplane.
,, 24.—Dillingen: Attacked by a flight of sixty-two aeroplanes.
,, 25.—Forest of Houlthulst: Bombed by sixty aeroplanes.
Sept. —In eighteen days there were forty aerial combats.
Nov. 30.—Off Ostend: a submarine was sunk by an aeroplane.
Dec. 20.—Forty-four aerial combats took place.

Sir John French's report of 15th October 1915, covering the period from 15th June 1915, states that there had been more than 240 combats in the air, chiefly behind the German lines.

Similar achievements to those recorded in the above schedule have been frequently repeated, until—wonderful though they are—they have almost become too commonplace for more than a small news item space in the columns of the daily Press. Many flights and numerous fights cannot, of course, be reported for military reasons.

It is of great interest to note that often the flights, or rather one might almost say swarms, of aeroplanes often total large numbers. As many as sixty-two are recorded in the above list as being in operation at once in one large body.

AEROPLANE ENGINES

Practically every motor car works in the country is now fully employed in the construction of either complete aeroplane engines, or of parts therefor. Particulars of the official Government designs are not available for publication, but it may be mentioned that they are evidently based on those of the engines which took part in the War Office trials of 1914. Details of these engines are given on the back of the table facing p. 82. As stated in the introduction to this book, the output of the largest individual engines has now been increased to about 300 horse-power, with twelve cylinders and a normal engine speed of 2,200 r.p.m.

GERMAN AEROPLANES

	Span.		Overall Length.		Area.	Horse-Power.
BIPLANES.	Ft.	In.	Ft.	In.	Sq. Ft.	
Albatross - - -	43	10	27	6	465	100
,, (scouting) -	37	0	2	0	400	160
Aviatik - - -	48	9	32	10	400	100
L. F. G. - - -	45	6	27	3	475	100
Rumpler-Taube - -	39	8	25	6	355	100
MONOPLANES.						
Albatross - - -	44	6	30	6	325	128
Etrich-Taube - -	43	6	30	0	355	100
Gotha-Taube - -	42	8	29	10	325	100
Rumpler-Taube - -	42	8	29	10	325	100
Fokker - - -	39	9	24	6	246	80

All the above aeroplanes are equipped with either Argus or Mercedes vertical type engines, with the exception of the Fokker, which has an 80 h.p. Uberusel petrol motor. The latest Fokker scouting machine is fitted with a very powerful engine of about 160 h.p. Captured Fokker and Albatross aeroplanes were placed on exhibition at the Horse Guards' Parade, Whitehall, London, in November 1915.

The German word "Taube" is employed on account of the similarity of the shape of the machines to that of a flying dove or pigeon.

(For examples of British and French aeroplanes, see pp. 84-99.)

GERMAN AIR RAIDS ON ENGLAND

	Killed	Injured
1914		
Dec. 24.—Dover - - -	—	—
1915.		
Jan. 19.—Yarmouth and King's Lynn	4	—
Feb. 21.—Colchester - - -	—	—
April 14.—Tyneside - - -	—	1
,, 15.—Lowestoft and Maldon -	—	—
,, 16.—Faversham - - -	—	—
,, 29.—Ipswich and Bury St Edmunds	—	—
May 10.—Southend - - -	1	1
,, 16.—Ramsgate - - -	1	3
,, 27.—Southend - - -	2	4
,, 31.—London District - -	6	—
June 1.—East and South-East Coast	—	—
,, 5.— ,, ,, ,, -	24	40
,, 7.—East Coast - - -	5	40
,, 15.—North-East Coast - -	16	40
July 3.—Harwich - - -	—	—
Aug. 9.—East Coast - - -	6	23
,, 17.—Eastern Counties - -	10	36
Sept. 7.— ,, ,, - -	13	43
,, 8.— ,, ,, and London	20	86
,, 11.—East Coast - - -	—	—
,, 12.— ,, ,, - - -	—	—
,, 13.—Coast of Kent - -	—	7
Oct. 13.—Eastern Counties and London	56*	114†
1916.		
Jan. 23.—Dover - - - -	1	6
,, 31.—Eastern, North-Eastern, and Midland Counties - -	59	101
Totals -	224	545

* 15 soldiers. † 13 soldiers.

This table demonstrates how useless these raids are, from [a] military point of view.

During the first twelve months of the War, 21 airship and [8] aeroplane raids were made on France.

Over 18 Zeppelins and 10 other airships have been lost by th[e] enemy since the beginning of the War.

THE AVIATION POCKET-BOOK

DIVISION I

AIR PRESSURE AND RESISTANCE

AIR RESISTANCE

THE resistance experienced by an aeroplane when in flight may be divided into three parts: (*a*) The "aerodynamic resistance," or "drift," of the sustaining surfaces; this is the horizontal component of the pressure on the aerofoils, and depends upon the angle at which they are set. (*b*) The "head resistance" of other portions of the aeroplane, caused by obstructions to the free flow of air. (*c*) The "skin friction," or resistance due to surfaces tangential to the motion of the air stream.

As an example of the resistance offered by the various component parts of an aeroplane, the following table, prepared by Lanchester, is of interest. It deals with the Wright and Voisin (Farman) types of flyers as constructed in the early part of 1909, and is based on the gliding gradient tan γ = Wright 0·135 and Voisin 0·15.

		Wright. lbs.	Voisin. lbs.
	Skin friction, $\xi = 0{\cdot}01$	40	60
Head Resistance	Struts and wires	30	20
	Aviator, motor, etc.	20	10
	Radiator and tanks	5	25
	Chassis	...	10
Drift.	Sustentation (power expended aerodynamically)	60	100
	Total	155	225

We will first consider the head resistance: the only trustworthy values are those obtained from experiment. Three main methods of experiment have been used: (1) The "whirling table," in which the body experimented upon is placed on the end of an arm rotating rapidly in the air. (2) The "wind tunnel," in which the bodies are mounted in a special channel, through which a current of air is made to pass. (3) The method used by M. Eiffel, in which planes were allowed to fall from a height, and their resistance calculated from measurements of their velocity.

The whirling table method, used notably by Dines and Langley, cannot be relied upon to give accurate absolute values, although useful for comparative tests. The wind tunnel method is reliable if the surface experimented on is not more than 0·7 per cent. of the area of the channel; a more uniform current can be obtained by drawing the air through the channel than by blowing it through. Stanton, Eiffel, and Riabouchinsky are the chief experimenters by this method.

All experimenters are agreed that :—

(1) For very low speeds - - - - $R \propto V$

(2) For ordinary speeds and up to about 160 ft. per second - - - - $R \propto V^2$

(3) For speeds above 160 ft. per second - $R \propto V^n$ where n is greater than 2.

Where R = head resistance due to an air current of velocity V.

It is probable that as velocities comparable with that of sound are reached the index n in (3) above increases very rapidly.

The **resistance per unit of area** appears to vary somewhat with the size of the surface exposed to the air, being rather less with small plates, and increasing to a limiting value when the surface is about 5 sq. ft.

For ordinary velocities, therefore, the law of atmospheric resistance to a surface at right angles to an air current may be given as—

$$R = z.\frac{w}{g}.\ S.V^2,$$

Where R = head resistance.

z = a coefficient, varying slightly with the size of surface.
w = weight of unit volume of air (density).
S = area of normal surface.
V = velocity of air current.
g = the acceleration of gravity.

It may be noticed that this formula holds with the same coefficient for fluids of different densities if the appropriate values for the densities are introduced into the equation, if the viscosities are the same.

The form in which the equation is directly of use is that in which z, g, and w are incorporated in a single constant; writing K for $\frac{z.w}{g}$, we have—

$$\mathbf{R = KSV^2}.$$

It should be noticed that the value of K is affected by the height of the barometer and by the temperature, since alterations in either of these cause variations in the density of the air, whose value is included in the constant K. The following formula is given by Eiffel :—

$$\frac{dK}{K} = \frac{dH}{H} - \frac{dT}{273 + T},$$

Where H = mean pressure in millimetres of mercury.
T = mean temperature in degrees Centigrade.
And dK, dH, dT are the small changes in K, H, and T respectively.

This means that a decrease in temperature from 18° to 15° C. (64·4° to 59° F.), or a rise in the barometric pressure of about 7 mm., will cause an increase in the value of K of, roughly, 1 per cent.

The following tables give the results of the most important experiments which have been performed. The values for the constant are given for different notations, as under :—

$p=z\frac{w}{g}sv^2$ - - Where all the quantities are in absolute units.

$P=KSV^2$ - - P in lbs. weight; S in square feet; V in miles per hour.

$P_1=K_1S_1V_1^2$ - - P_1 in lbs. weight; S_1 in square feet; V_1 in feet per second.

$P_2=K_2S_2V_2^2$ - - P_2 in kilogrammes weight; S_2 in square metres; V_2 in kilometres per hour.

$P_3=K_3S_3V_3^2$ - - P_3 in kilogrammes weight; S_3 in square metres; V_3 in metres per second.

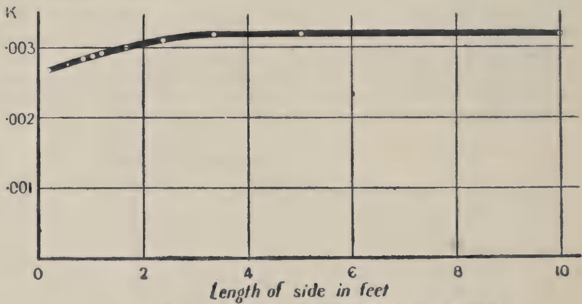
The conversion factors are as follows :—

$$z=191{\cdot}9\ K, \quad =412{\cdot}8\ K_1, \quad =103{\cdot}7\ K_2, \quad =8{\cdot}00\ K_3.$$
$$K=2{\cdot}151\ K_1, \quad =\cdot 5304\ K_2, \quad =\cdot 04092\ K_3.$$
$$K_1=\cdot 2466\ K_2, \quad =\cdot 0190\ K_3.$$
$$K_2=\cdot 07716\ K_3.$$

Coefficients of Normal Pressure on Square Plates

Experimenter.	z.	K.	K_1.	K_2.	K_3.	Size of Plate. Ft. In	Remarks.
Stanton	·52	·0027	·00126	·0051	·066	0 2 sq.	Wind tunnel method.
Cailletet	·55	·0028	·00133	·0054	·070	0 6 ,,	.. ..
Eiffel -	·55	·0028	·00133	·0054	·070	0 10 ,,	Falling plate method.
Dines -	·56	·0029	·00135	·0055	·071	1 0 ,,	{ Corrected value. Whirling table method
Eiffel -	·56	·0029	·00136	·0055	·071	1 2 ,,	Falling plate method.
,,	·59	·0030	·00142	·0058	·075	1 8 ,,	,,
,,	·61	·0031	·00147	·0059	·077	2 3 ,,	,,
,,	·62	·0032	·00150	·0061	·079	3 3 ,,	,,
Stanton	·62	·0032	·00148	·0060	·078	5 0 ,,	Plates exposed to wind.
,,	·62	·0032	·00149	·0060	·078	10 0 ,,	,,

The subjoined curve, due to Dr Stanton, shows the increase in **K** with the size of the plate up to a limiting value at ·0032 for plates of above 3 ft. 6 in. side.



NORMAL PRESSURE ON SQUARE PLATES.

FIG. 1.

Messrs Bairstow and Booth, of the National Physical Laboratory, have recently given the following formula for the resistance of a square plate in a current of air :—

$$R = \cdot 00126\ (vl)^2 + \cdot 0000007\ (vl)^3,$$

Where v is in feet per second, and equals velocity of air current.
l is in feet, and equals the length of side of the plate.

Circular Plates.—The pressure on circular plates varies with their size in a similar manner. Eiffel's experiments gave results as under :—

NORMAL PRESSURE ON CIRCULAR PLATES (Eiffel)

Area.	z.	K.	K_1.	K_2.	K_3.
Sq. Ft.					
·67	·54	·0028	·00129	·0052	·068
1·34	·57	·0029	·00135	·0055	·071
2·69	·59	·0030	·00141	·0057	·074
5·38	·62	·0032	·00147	·0059	·077
10·76	·62	·0032	·00147	·0059	·077

The coefficient increases with the size of the plate, as with square plates, and to the same limiting value.

Rectangular Plates.—In the case of rectangular plates the coefficient is affected by the ratio of the length of the plate to its breadth. The following results were obtained by Dr Stanton, using small plates in a wind tunnel.

NORMAL PRESSURE ON SMALL RECTANGULAR PLATES

Size of Plate.	Ratio, Length to Breadth	K.
In.		
2 × 2	1	·0027
3 × 1	3	·0028
$2\frac{1}{2} \times \frac{1}{2}$	5	·0029
$5 \times \frac{1}{2}$	10	·0032
6 × ·3	20	·0035

These values are plotted below.

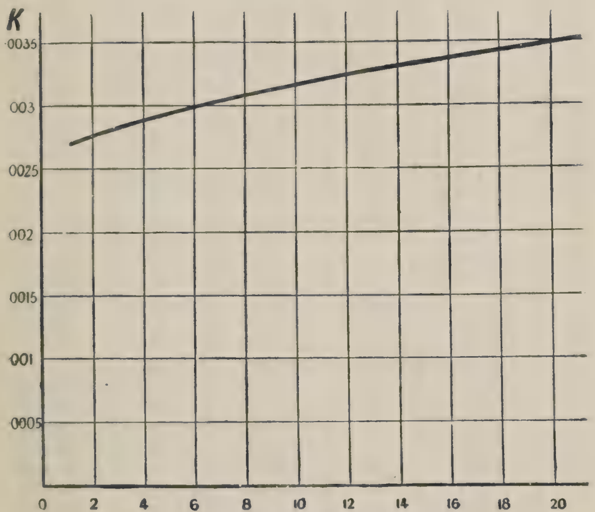


FIG. 2.

The conclusion to be drawn from the foregoing tables is that for calculations as to the resistance experienced by a surface normal to

the wind and of moderate size, it is safe to take for K the value 0·0032, at 760 mm. and 60° F.

$$R = 0·0032\ SV^2,$$

Where R is in lbs. weight.
S is in square feet.
V is in miles per hour.

The following tables give the resistance calculated by this formula and by the corresponding formula $R = 0·00149\ sv_1^2$, where v_1 is in feet per second.

Air Resistance

Velocity.	Pressure.	Velocity.	Pressure.	Velocity.	Pressure.
Miles per Hour.	Lbs. per Ft.^{2}	Miles per Hour.	Lbs. per Ft.^{2}	Miles per Hour.	Lbs. per Ft.^{2}
10	·320	41	5·379	72	16·589
11	·387	42	5·645	73	17·052
12	·461	43	5·917	74	17·524
13	·541	44	6·195	75	18·000
14	·627	45	6·480	76	18·483
15	·720	46	6·771	77	18·972
16	·819	47	7·068	78	19·469
17	·925	48	7·372	79	19·971
18	1·037	49	7·683	80	20·480
19	1·155	50	8·000	81	20·997
20	1·280	51	8·323	82	21·517
21	1·411	52	8·652	83	22·045
22	1·549	53	8·989	84	22·579
23	1·693	54	9·331	85	23·120
24	1·843	55	9·680	86	23·666
25	2·000	56	10·035	87	24·221
26	2·163	57	10·397	88	24·780
27	2·333	58	10·764	89	25·349
28	2·509	59	11·139	90	25·920
29	2·691	60	11·520	91	26·501
30	2·880	61	11·907	92	27·085
31	3·075	62	12·300	93	27·678
32	3·277	63	12·701	94	28·276
33	3·485	64	13·107	95	28·881
34	3·699	65	13·520	96	29·491
35	3·920	66	13·937	97	30·109
36	4·147	67	14·364	98	30·734
37	4·381	68	14·796	99	31·360
38	4·621	69	15·237	100	32·000
39	4·867	70	15·680	120	46·083
40	5·120	71	16·130		

AIR RESISTANCE

Velocity.	Pressure.	Velocity.	Pressure.	Velocity.	Pressure.
Ft. per Sec.	Lbs. per Ft.^{2}	Ft. per Sec.	Lbs. per Ft.^{2}	Ft. per Sec.	Lbs. per Ft.^{2}
16	·38	62	5·73	108	17·38
18	·48	64	6·10	110	18·03
20	·60	66	6·49	112	18·69
22	·72	68	6·89	114	19·36
24	·86	70	7·30	116	20·05
26	1·01	72	7·72	118	20·74
28	1·17	74	8·16	120	21·46
30	1·34	76	8·61	122	22·18
32	1·53	78	9·06	124	22·91
34	1·72	80	9·54	126	23·65
36	1·93	82	10·02	128	24·41
38	2·15	84	10·51	130	25·18
40	2·38	86	11·02	132	25·96
42	2·63	88	11·54	134	26·75
44	2·88	90	12·07	136	27·56
46	3·15	92	12·61	138	28·38
48	3·43	94	13·17	140	29·20
50	3·73	96	13·73	142	30·04
52	4·03	98	14·31	144	30·90
54	4·34	100	14·90	146	31·76
56	4·67	102	15·50	148	32·64
58	5·01	104	16·11	150	33·52
60	5·36	106	16·74	200	59·60

Distribution of Pressure on Normal Plates.—According to Stanton, the compression at the centre of the front face of a plate in a current of air is the same for all surfaces, and is equal to $\frac{\delta}{2g}V^2$.

He found the suction on the back face practically uniform except near the edges, but the value varies according to the form of the surface. The figure represents the pressure on the centre line of a rectangle, 3 by 1 in.

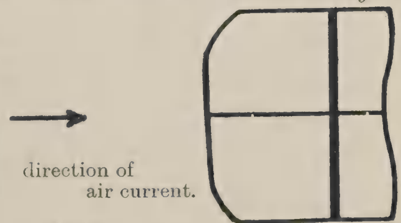


FIG. 3.

The leakage of air over the edges is clearly shown by the diminu-

tion of pressure; the large effect of suction on the back of the plate is also shown.

Experiments made by Nipher show much the same results. The tables below were calculated by Eiffel from the results of Nipher's experiments; taking 100 as the maximum pressure, the pressures at different points on the plate are shown by proportional figures. 57 per cent. of the total pressure was found to be on the front face, and 43 per cent. on the back.

FRONT FACE

53	57	57	57	57	57	57	57	57	57	57	53
53	79	79	79	79	79	79	79	79	79	79	53
53	82	83	93	93	93	93	93	93	83	82	53
53	82	88	93	100	100	100	100	93	88	82	53
53	82	88	93	96	96	96	96	93	88	82	53
53	82	88	93	100	100	100	100	93	88	82	53
53	82	83	93	93	93	93	93	93	83	82	53
53	79	79	79	79	79	79	79	79	79	79	53
53	57	57	57	57	57	57	57	57	57	57	53

BACK FACE

40	48	48	48	48	48	48	48	48	48	48	40
53	53	53	53	53	53	53	53	53	53	53	53
53	53	55	56	56	56	56	56	56	55	53	53
53	53	62	61	57	57	57	57	61	62	53	53
53	62	62	64	62	62	62	62	64	62	62	53
53	53	62	61	57	57	57	57	61	62	53	53
53	53	55	56	56	56	56	56	56	55	53	53
53	53	53	53	53	53	53	53	53	53	53	53
40	48	48	48	48	48	48	48	48	48	48	40

Perforations in Plates.—It has been shown that a considerable number of perforations may be made in a plate without seriously altering the air pressure upon it.

Remaining Area of Plate.	Ratio of Pressure to Pressure on Unperforated Plate.
1·0	1·0
·90	1·0
·6	·9
·1	·12

Shielding.—The results of experiments on the shielding effect of one plate placed in front of another are given below, for equal circular plates :—

Distance apart of Plates, in Terms of the Diameter.	Ratio of Air Pressure on both Plates to that on a Single Isolated Plate.	
	Eiffel (Plate, 15¾ in. diameter).	Stanton (Plate 1·97 in. diameter).
0·5	·96	...
1	·83	...
1·5	·75	less than ·75
2·15	...	1
5	...	1·78
10	...	2

Stanton found similar results with square plates, but he noticed a considerably less shielding effect in the case of rectangles with a high ratio of length to breadth.

Head Resistance of Bodies of Particular Shapes.—The head resistance of a body of any shape is given by

$$R = K^1SV^2,$$

Where K^1 is an appropriate constant.
S is the projected area of the body normal to the wind.
V is the velocity of the wind in miles per hour.

In the list of formulæ given below, K^1 is the constant just defined, and the ratio $\frac{K^1}{K}$ is calculated for a value of $K = \cdot0032$, unless it is otherwise stated.

Body.	K.	$\frac{K^1}{K}$.	Authority.	Remarks.
Round bar - - - - - -	·0022	·69	Maxim	$R = K^1 l d V^2$.
Cylinder, side to wind - - -	·0019	·596	Renard	... ...
Do. do. - - -	·0034	1·12	Lössl	... ...
Square bar, side to wind - -	·0039	1·22	Maxim	... ...
Do., diagonal to wind -	·0029	·906	,,	$R = ·0041\ al\,V^2$, where a = side of square in feet, l = length of bar.
Elliptical bar, major axis = twice minor axis	·0013	·407	,,	$R = ·0013\,blV^2$, where b = minor axis of ellipse.
Oval bar, sharp edges, width = 6 times thickness	·00016	·05	,,	... ...
Bar of fish-shaped section, length = 4·5 times thickness	·000195 (thick end to wind)	·061	,,	... ...
Do. do.	·0005 (thin end to wind)	·156	,,	... ...
Sphere - - - - - -	·0017	·531	Lössl	$R = ·0017\ \pi r^2 V^2$, where r = radius of sphere.
Do. - - - - - -	·0006	·159	Renard	$R = K^1 \pi r^2 V^2$.
Hemisphere, convex side to wind -	·0017	·531	Lössl	... ...
Do. do.	·0013	·392	Renard	... ...

Hemisphere, concave side to wind	·0051	1·594	Lössl	... ...
Do. do.	·0045	1·406	Renard	... ...
Do. do.	·0034	1·063	Eiffel	Original experiment.
Do. do.	·0038	1·188	,,	Latest experiment.
Convex side to wind, base at 45°	·0016	·500	Lössl	In these cases the formula is $R = K^1 S_1 V^2$, where S_1 is not the projected area, but the area of the base of the hemisphere, *i.e.*, $R = K^1 . \pi . r^2 V^2$.
Do. do., base at 22½°	·0014	·438	,,	
Base parallel to direction of wind	·0011	·344	,,	
Concave side to wind, base at 6°	·0013	·406	,,	
Do. do., base at 22½°	·0022	·688	,,	
Do. do., base at 45°	·0037	1·156	,,	
Do. do., base at 60°	·0043	1·344	,,	
Cylinder end on—Ratio $\frac{\text{Length}}{\text{Diameter}}$:—				Cylinders with plane ends :— The cylinders experimented on by Dr Stanton were small, and a flat circular plate of the same diameter gave a coefficient K = ·0028. $\frac{K^1}{K}$ is therefore calculated for this value of K. For M. Eiffel's cylinders the ordinary value K = ·0032 has been used, the diameter of the base being 12.5 cm.
= 0·48	·0027	·98	Stanton	
= 0·5	·0029	·91	Eiffel	
= 0·97	·0024	·86	Stanton	
= 1·0	·0028	·88	Eiffel	
= 1·21	·0021	·77	Stanton	
= 1·45	·0016	·64	,,	
= 1·5	·0021	·66	Eiffel	
= 2·42	·0019	·70	Stanton	
= 2·68	·0028	·88	Franck	
Ends conical, inclined at 45° to axis	·0019	·59	,,	Ratio $\frac{\text{Length}}{\text{Diameter}} = 2·68$; diameter of base 5·6 cm.

(*Continued on next page.*)

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Body.	K.	$\frac{K^1}{K}$.	Authority.	Remarks.
Ends conical, inclined at 30° - -	·0018	·56	,,	... ...
Ends hemispherical - - -	·0013	·41	,,	... ...
Ends ellipsoidal, diameter = half major axis	·0012	·38	,,	... ...
Do., diameter = major axis - -	·0011	·34	,,	... ...
Square prism, end on—plane base -	·0026	·81	,,	... ...
End of prism, pyramids formed of equal triangles	·0018	·56	,,	... ...
Wedge, semi-vertical angle = 70° -	·0028	·9	Eiffel	The ratios $\frac{K^1}{K}$ are those given by M. Eiffel, calculated from K for a flat plate of the same projected area on the wedge.
Do. do., = 47½° -	·0024	·78	,,	
Do. do., = 28° -	·0016	·54	,,	
Cone, vertical angle 60° - - -	·0006	·19	,,	End of cone open.
Do., point to wind - - - -	·0007	·22	,,	End of cone closed by hemisphere.
Spindle-shaped body, ratio $\frac{l}{b}=2$ -	·00024	·073	Renard	$R=K^1\pi r^2V^2$, where r = radius at greatest diameter.
Do., ratio $\frac{l}{b}=3$ - - - -	·0001	·032	,,	... ...
Do., ratio $\frac{l}{b}=2$, side to wind - -	·0014	·433	,,	... ...

Wires.—It has been stated frequently that the resistance of a "singing" or vibrating wire is greater than that of a wire at rest, but experiments conducted by Dr Stanton failed to give any evidence of this. He obtained the following results from a horizontal wire:—

Wire steady - - - - - - -	$K^1 = \cdot 00118$
,, vibrating in vertical plane - -	·00120
,, steady - - - - - - -	·00116
,, vibrating in horizontal plane - -	·00116

Maxim's original results on the resistance of bars were as follows:—

STRUT RESISTANCES (Maxim)

Resistance (lbs. per foot run) for Different Sections

Section.	Beam.	Entrance.	Run.	Axis in Wind.	Drift per Ft.	Velocity.
	In.	In.	In	In.	Lbs.	M.P.H.
Square section bar, 2-in. edge, face to wind -	2·00	..	..	..	1·550	40
,, ,, ,, 2-in. ,, edge ,, -	2·83	..	..	..	1·820	49
Round ,, ,, 2-in. diam. - - -	2·00	..	..	..	·930	40
Kite ,, ,, blunt edge to wind -	2·00	3	6	9	·260	40
,, ,, ,, sharp ,, ,, -	2·00	6	8	9	·400	40
Fish ,, ,, blunt ,, ,, -	2·00	3	6	9	·090	40
,, ,, ,, sharp ,, ,, -	2·00	[illegible]	[illegible]	[illegible]	·140	40
Bottle ,, ,, blunt ,, ,, -	2·00	3	6	9	·076	40
,, ,, ,, sharp ,, ,, -	2·00	6	3	9	·196	40
Elliptic ,, ,, (symmetrical) - -	2·00	6	6	12	·063	40

Pressure on Inclined Surfaces.—The resultant pressure on a flat plate inclined to a current of air is stated by Langley and Dines to be normal to the surface: Stanton and Eiffel came to the conclusion that the resultant pressure made an angle with the normal to the surface of the order of 1°.

The horizontal force on an inclined plane equals the head resistance added to the "drift," or horizontal component of the normal pressure: the vertical force consists of the vertical component of the normal pressure on the plane.

Several determinations of the variation of the pressure on square plates with the angle of inclination have been made, of which the following are the most important results:—

NOTE.— $P\alpha$ = Normal pressure on plane set at an angle to air current of $\alpha°$.

$P_{90°}$ = Normal pressure on plane set at right angles to air current.

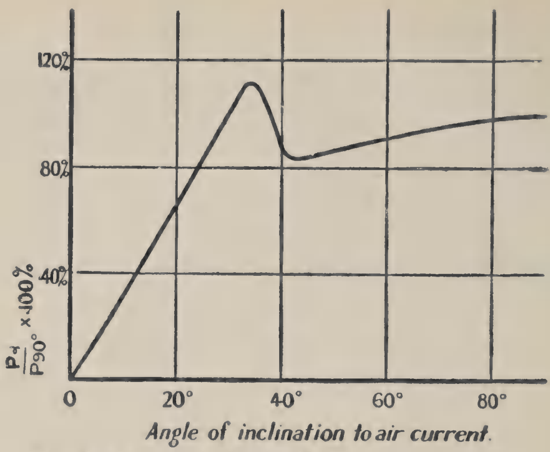


FIG. 4.—Pressure on Inclined Square Plates (Dines).

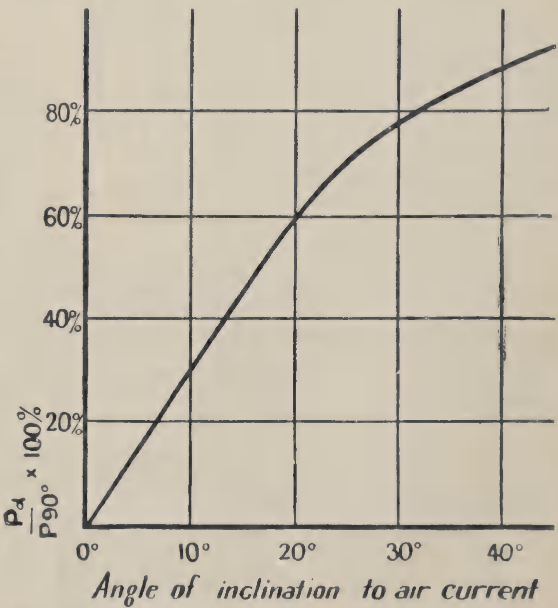


FIG 5.—Pressure on Inclined Square Plates (Langley).

The following formulæ have been proposed, most of them being based upon the experiments of the author of the formula :—

Square Plates

$\frac{P\alpha}{P_{90°}}$.	Becomes for Small Angles.	Authority.	Remarks.
$\frac{2 \sin \alpha}{1 + \sin^2 \alpha}$	$2 \sin \alpha$, or $2\,\alpha$	Duchemin	This agrees closely with Langley's experiments.
$2 \sin \alpha - \sin^3 \alpha$	$2 \sin \alpha$, or 2α	Renard	Based on Renard's experiments.
Sin 2α, when α is not greater than 45°	$\sin 2\alpha$, or 2α	Institut de Koutchino	Based on experiments of Riabouchinsky.
1, when α is greater than 45°	...	,,	,, ,,
$\frac{\alpha°}{30}$, when α is not greater than 30°	$\frac{\alpha°}{30}$	Eiffel	Based on original Eiffel Tower experiments.
$\frac{\alpha°}{25}$, when α is not greater than 30°	$\frac{\alpha°}{25}$	,,	Based on M. Eiffel's latest experiments.
= 1, when α is greater than 30°	...	,,	,, ,,
Sin α	$\sin \alpha$, or α	Lössl	,, ,,

Inclined Circular Disc.—The following results are given by Mannesmann :—

a	15°	23°	30°	37½°	41°	45°
$\frac{Pa}{P_{90}°}$	·19	·343	·610	·820	·887	·936

a	60°	67½°	75°	82½°	90°
$\frac{Pa}{P_{90}°}$	1·002	1·036	1·060	1·029	1·0

Inclined Rectangular Planes.—Stanton experimented on a plate 3 by 1 in., taking readings with the plate both end on and broadside on to the current. His results are given in the curve below. The advantages of a high aspect ratio are clearly shown.

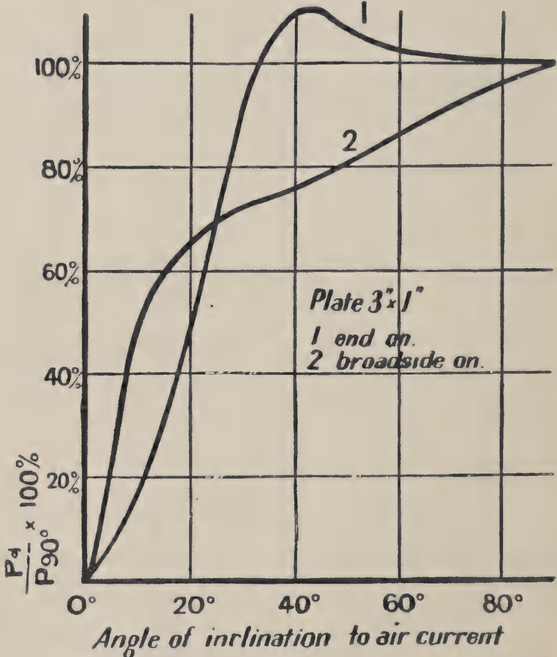


FIG. 6.—Pressure on Inclined Rectangular Plates (Stanton).

Finzi and Soldati experimented on plates 45 cm. wide and 85, 54, 30, and 10 cm. deep, giving aspect ratios of ·53, ·83, 1·5, and 4·5 respectively. Their results are given in the curve below.

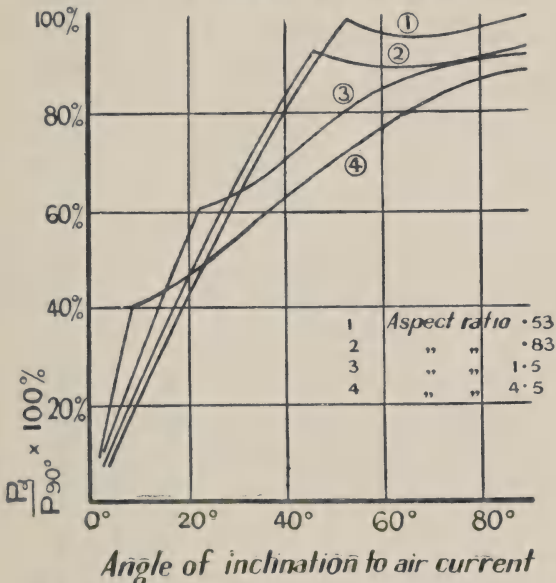


FIG. 7.—Pressure on Inclined Rectangular Plates (Finzi and Soldati).

Soreau has given the following formula for the pressure on rectangular plates inclined to a current of air :—

$$\frac{P\alpha}{P_{90^\circ}} = \sin\alpha\left[1 + \frac{1 - m\tan\alpha}{\frac{1}{(1+m)^2} + \frac{2m}{1+m}\tan\alpha + 2\tan^2\alpha}\right].$$

Where $m = \frac{l-h}{l+h}$, $2l$ being the horizontal side of the rectangle, and $2h$ the inclined side.

It will be seen that for a square plate this formula reduces to $\frac{P\alpha}{P_{90^\circ}} = \frac{2\sin\alpha}{1+\sin^2\alpha}$, which is identical with Duchemin's formula.

Distribution of Pressure on Inclined Plates.—Stanton gives the following curves, showing the pressure on the front and the suction on the back of a plate 3 by 1 in. inclined end on to a current of air. The pressures are measured at the median line of the plate.

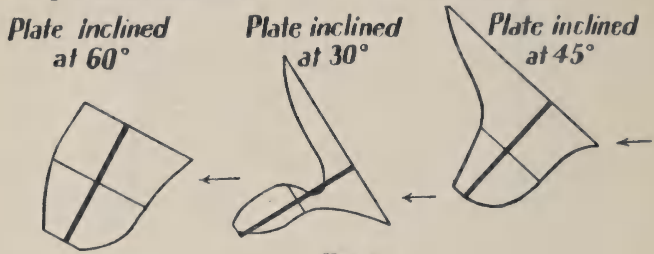


FIG. 8.

Centre of Pressure on Inclined Planes.—The most reliable results are shown in the following curves :—

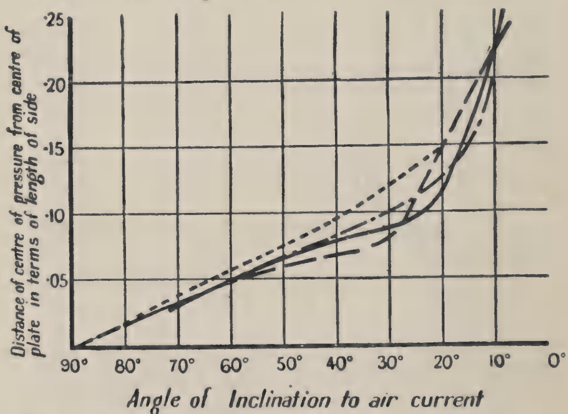


FIG. 9.—Centre of Pressure on Inclined Plates (Kummer, Langley, Finzi and Soldati, Dines).

The following formulæ have been proposed :—

1. By Joessel, from his experiments on plates immersed in water—

$$x = 0{\cdot}3[1 - \sin \alpha],$$

Where $$x = \frac{\text{distance of C.P. from centre of plate}}{\text{length of inclined side of plate}}.$$

2. By Thiesen—

$$x=0\cdot 2\frac{\cos\alpha}{1+\sin\alpha}.$$

3. By Soreau—

$$x=\frac{1}{4[1+2\tan\alpha]}.$$

This formula of Soreau's agrees very well with the results found by Langley and Dines up to an inclination of 20°, but is probably inaccurate for larger inclinations.

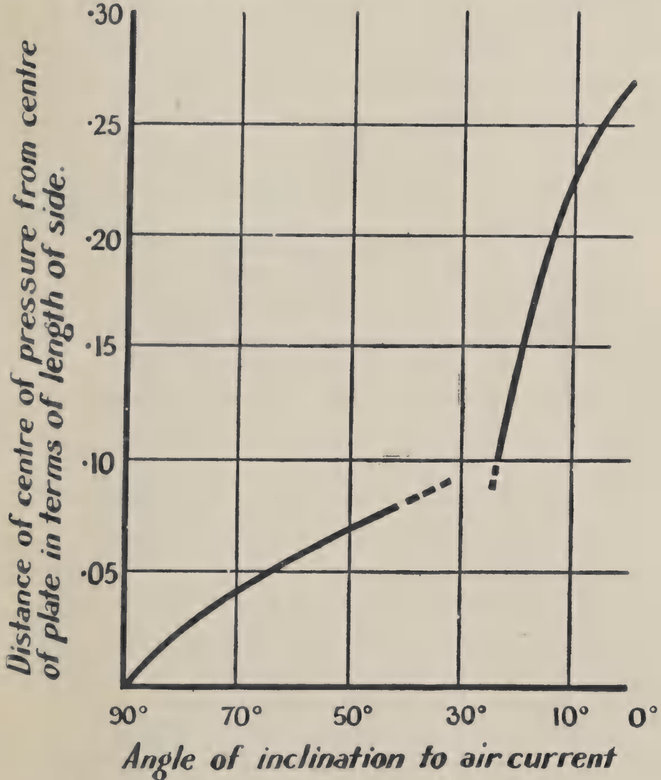


Fig. 10.—Centre of Pressure on Inclined Plates (Rateau).

The following table will show the amount of agreement between different authorities :—

α	Formulæ.		Experiments.	
	Joessel.	Soreau.	Dines.	Langley.
10 - -	·247	·185	·200	...
20·5 - -	·197	·143	·125	·146
45 - -	·088	·083	·075	·083
78 - -	·006	·024	·020	·021

Pressure on Inclined Curved Surfaces.—The earliest experiments on this subject were those made by Lilienthal. The camber of his aerofoil was $\frac{1}{12}$: his results are shown in the curve below.

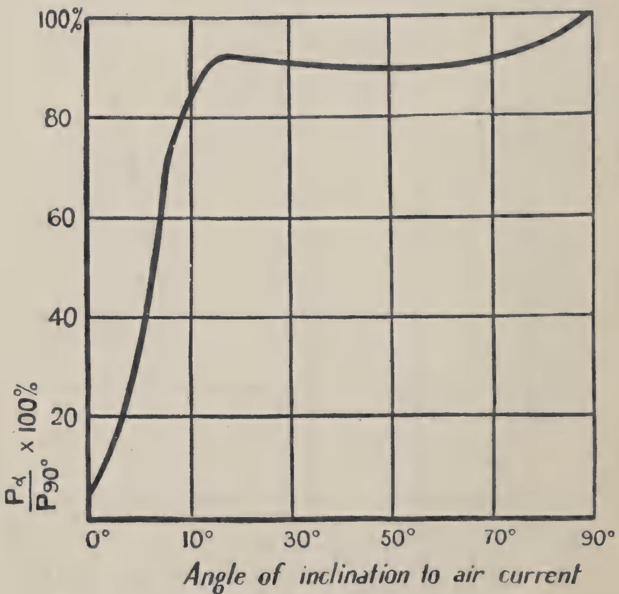


FIG. 11.—Pressure on an Inclined Aerofoil (Lilienthal).

Eiffel experimented with a curved plane of camber $\frac{1}{13{\cdot}5}$, span 90 cm., chord 15 cm., giving an aspect ratio of 6. The curve below shows his results.

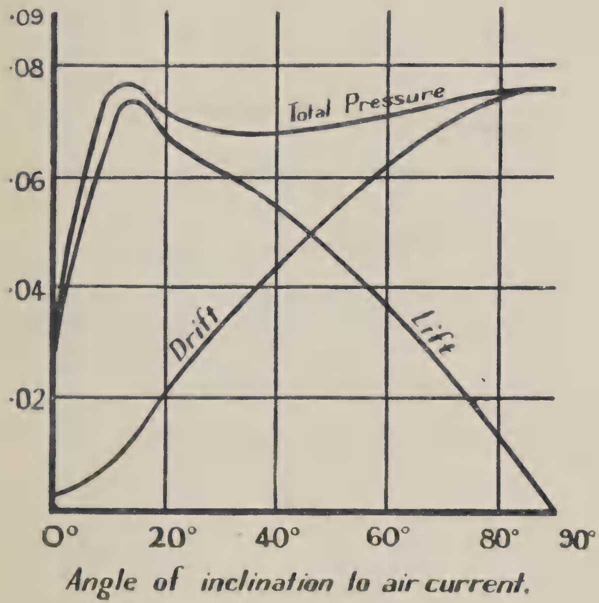


FIG. 12.—Pressure on an Inclined Aerofoil (Eiffel).

The maximum lift and total pressure both occur when the leading edge of the plane is tangential to the air current.

Centre of Pressure on Curved Surfaces.—Sellers has determined the position of the centre of pressure at varying angles for four different shapes of aerofoil. The aerofoils used were 6 by 12 in.

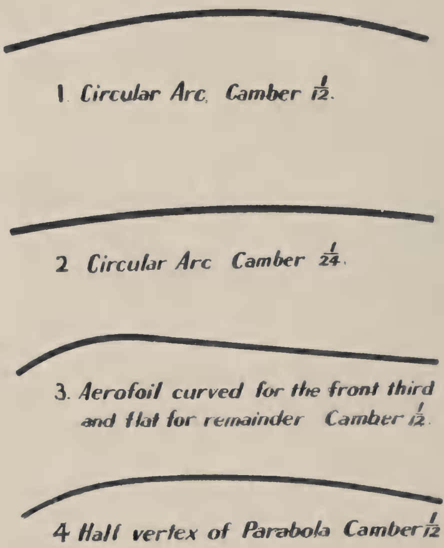


FIG. 13.—Shapes of Aerofoils in Sellers' Experiments.

No difference was found in the position of the centre of pressure for different velocities of the air current.

Wilbur Wright has referred in general terms to the movement of the centre of pressure on an aerofoil as follows: "In deeply curved surfaces the centre of pressure at 90° is near the centre of the surface, but moves forward as the angle becomes less, till a certain point is reached varying with the depth of the curvature. After this point is passed the centre of pressure, instead of continuing to move forward with the decreasing angle, turns and moves rapidly towards the rear. These phenomena are due to the fact that at small angles the wind strikes the forward part of the surface on the upper side instead of the lower, and thus this part altogether ceases to lift, instead of being the most effective part of all as in the case of the plane." It will be seen that the above quotation is amplified by Sellers' experiments.

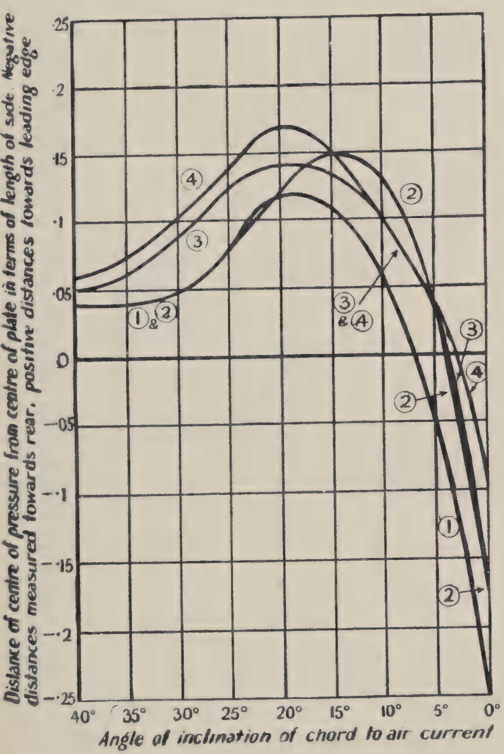


Fig. 14.—Centre of Pressure on an Inclined Aerofoil (Sellers).

The backward movement of the centre of pressure at small angles is also shown, although in a less marked degree, by Eiffel's results, on an aerofoil of circular curvature, camber $\frac{1}{13 \cdot 5}$, and of dimensions 90 by 15 cm., giving an aspect ratio of 6.

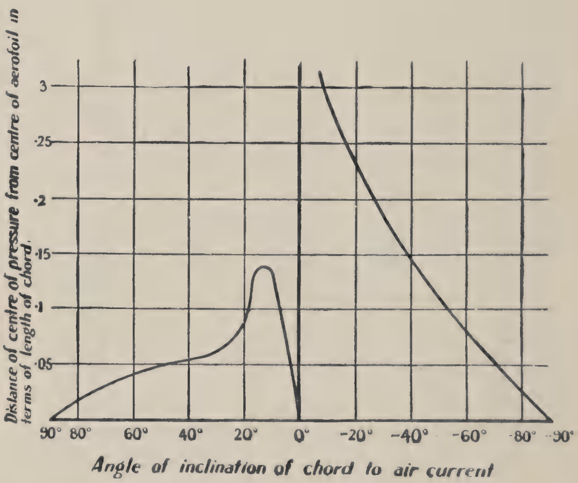


FIG. 15.—Centre of Pressure on an Inclined Aerofoil (Eiffel).

Skin Friction.—The most reliable experiments have been made by Zahm; he used boards varying in length from 2 to 16 ft., and observed the skin friction at velocities from 5 to 20 miles per hour.

The formula deduced from his experiments by Professor Zahm for smooth plates is as under:—

$$R = \cdot 0000316\, l^{\cdot 93}\, V^{1 \cdot 85},$$

Where R = Resistance in lbs. per foot of span, double surface.
l = length of surface tangential to the wind, in feet, *i.e.*, length of chord.
V = Velocity in miles per hour.

SKIN FRICTION PER SQUARE FOOT FOR VARIOUS SPEEDS AND LENGTHS OF SURFACE

Wind Speed.	Average Friction in Lbs. per Square Foot.					
	1-ft. Plane.	2-ft. Plane.	4-ft. Plane.	8-ft. Plane.	16-ft. Plane.	32-ft. Plane.
M.P.H.						
5	0·000303	0·000289	0·000275	0·000262	0·000250	0·000238
10	0·00112	0·00105	0·00101	0·000967	0·000922	0·000878
15	0·00237	0·00226	0·00215	0·00205	0·00195	0·00186
20	0·00402	0·00384	0·00365	0·00349	0·00332	0·00317
25	0·00606	0·00579	0·00551	0·00527	0·00501	0·00478
30	0·00850	0·00810	0·00772	0·00736	0·00701	0·00668
35	0·01130	0·0108	0·0103	0·0098	0·00932	0·00888
40	0·0145	0·0138	0·0132	0·0125	0·0125	0·0114
50	0·0219	0·0209	0·0199	0·0190	0·0181	0·0172
60	0·0307	0·0293	0·0279	0·0265	0·0253	0·0242
70	0·0407	0·0390	0·0370	0·0353	0·0337	0·0321
80	0·0522	0·0500	0·0474	0·0452	0·0431	0·0411
90	0·0650	0·0621	0·0590	0·0563	0·0536	0·0511
100	0·0792	0·0755	0·0719	0·0685	0·0652	0·0622

Streamlines.—A streamline is the locus of the path of a particle of moving fluid: the following expression holds for the total energy of 1 lb. of fluid moving in streamlines :—

$$h + \frac{p}{w} + \frac{v^2}{2g},$$

Where h is the height above a datum level.
p ,, pressure.
w ,, weight per unit volume.
v ,, velocity of the fluid.
g ,, acceleration of gravity.

A "streamline form" is a body around which the streamlines are continuous, that is to say, a body which forms no eddies when placed in a current of air. It would appear that the length parallel to the current should be about six times the thickness, with the maximum thickness about a third of the distance from the front.

The reduction of head resistance by making everything possible of streamline form is of the greatest importance, since this reduces the gliding angle, upon which depends the amount of power required to drive the machine through the air; the possibility of "soaring" is also intimately connected with a reduction of the gliding angle.

DIVISION II

AEROPLANE THEORY AND DESIGN

ELEMENTARY THEORY OF THE AEROPLANE

It is doubtful whether any other than a comparatively elementary theory of the aeroplane is of much use, firstly, because so many factors enter into the research, and secondly, because of the uncertainty as to the influence these factors exert under different conditions. It appears doubtful if a complete theory, which will at the same time be of practical value to designers, will be formulated for some time; at any rate practice is for the time being ahead of theory, and the latter is only capable of general treatment.

Let AB, Fig. 16, be the inclined surface of the main plane, and let it be assumed that this plane can be moved in any direction while maintaining its horizontal inclination, or in other words, that it is mounted on a frame having freely running light wheels resting on the ground.

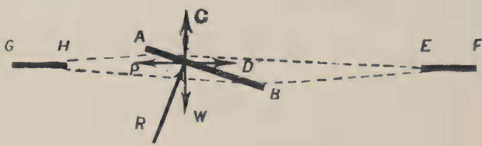


Fig. 16.

The aeroplane will be propelled by a screw exerting a force P, and we will imagine that there is no wind. The screw is started when the aeroplane is at rest, and there is consequently experienced at first only the slightest resistance to the plane moving forward. The speed is rapidly accelerated, however, and with increase of speed increasing resistance is experienced. This is due to the pressure of the air on the plane as it is urged forward.

Resulting from the above, we may assume a force R to be acting perpendicularly to the plane, and this can be resolved into its com-

ponents C in a vertical direction, and D in a horizontal direction. In magnitude these are proportional to the magnitude of the force R, which again depends on the speed, and it is evident that when C, the vertical component, becomes greater than the weight of the aeroplane, the latter must rise in the air. There is therefore a definite forward speed of the plane, below which it cannot be made to ascend, and this is the speed at which the upward force necessary to overcome the weight of the apparatus is attained.

The plane will continue to mount, due to the upward force C being greater than the weight of the apparatus W, but having reached a certain height the aviator will wish to absorb all the power of the propeller in forward movement and not in further lifting. To effect this end, the horizontal inclination of the plane must be altered, or something done which is equivalent thereto. When by this operation of altering the angle the force C is made exactly equal to the weight W, the aeroplane moves horizontally.

As the speed increases, the horizontal component D increases, because the greater the speed the greater is the resistance to motion offered by the air pressure. When moving horizontally at a uniform speed, the force P exerted by the screw propeller is equal to the resistance the apparatus experiences to its forward movement.

We see then that two conditions are necessary if the aeroplane is to fly in a horizontal direction at a uniform speed :—

(*a*) The vertical component C, due to the force R, must be equal to the weight of the machine.

(*b*) The force P, exerted by the propeller, must be equal to the resistance to the forward movement.

Main Planes.—It is on the main planes of the machine that its power to lift and remain suspended in mid air depends. The reasoning in the preceding paragraph will apply generally to all aeroplanes, but to resolve the forces in the actual machines is by no means simple. Instead of being perfectly flat, the planes are in practice curved, which gives a more efficient shape as regards lifting power, since the air is accelerated gradually and without shock. As the planes move forward the air is, as it were, scooped up and discharged behind them in a downward direction, the angle of discharge depending upon the curvature. The lifting is therefore due to reaction, and the problem becomes of a complex dynamical character rather than of a statical character, as would be indicated by the figures.

In any case we can imagine that the whole of the force acting to lift the planes is concentrated at one point on the surface, which may be called "the centre of pressure." Again, the whole weight of the machine can be supposed to be concentrated at its centre of gravity, and it is upon the adjustment, relatively to each other, of the centre of pressure and the centre of gravity that the stability of the machine depends.

If the centre of pressure were in front of the centre of gravity, the upward force acting at the former, and the downward force acting at the latter, would make the machine tip stem upwards; if, on the other hand, the centre of pressure were behind the centre of gravity, the machine would plunge stem downwards. When the machine is proceeding in a horizontal direction the centre of pressure coincides with the centre of gravity.

It so happens that the position of the centre of pressure alters with the inclination of the planes. It lies somewhere between the central transverse line of the plane and the front edge, approaching nearer the latter, up to a certain limit, as the angle of the plane to the horizontal diminishes, and receding from it as the angle increases. The effect of this is that, should the planes, due to gusts or other cause, be tilted to an abnormal angle (see p. 34), the movement of the centre of pressure is such as to produce a couple acting to restore the balance. The tail and the elevating planes tend to prevent any violent pitching due to the adjustment of the centre of pressure to the centre of gravity being disturbed.

Elevating Planes.—It will be gathered from the last paragraph that, when greater elevation is required, it is necessary to advance the centre of pressure, in order to produce a deflecting couple tilting the stem upwards. Conversely, when it is desired to descend, the centre of pressure must be moved backwards to produce a couple deflecting the machine downwards. It is the function of the elevating planes to enable these adjustments to be effected.

The elevating planes are supplementary to the main planes, and placed either before or behind them. Assume that in front of the main plane AB, Fig. 16, there is placed a plane of smaller dimensions GH, which is carried on a horizontal axle, and is therefore capable of being inclined at any desired angle. When lying horizontally, that is parallel to the motion of the machine, there will be no air pressure on the plane, but when it is inclined there will be a pressure on its surface depending upon the angle of inclination. Increasing or diminishing the upward force at one point of the system has the effect of moving the point at which the whole force is supposed to be concentrated. Accordingly the elevating planes furnish the means of advancing or retiring the centre of pressure, so that the machine can be caused to ascend or descend at will.

Tail.—The tail of an aeroplane consists of certain fixed planes employed to give stability to the machine. Let us suppose that there is placed well behind the main planes a fixed horizontal, or approximately horizontal, plane EF, Fig. 16. Suppose that when the aeroplane is proceeding horizontally, due to some force acting on the main planes, it tends to tip upwards at the stem. Consequent on the presence of the plane EF forming the tail, a certain amount of resistance is offered to oppose this occurrence, the downward movement of the plane being retarded in two ways, firstly, by the

air pressure produced on its lower side by the movement, secondly, by the reduction of pressure on its upper side. These two forces act in the same upward direction to oppose the tipping of the machine; conversely, if the machine has a tendency to plunge stem downwards, there are brought into existence forces acting on the tail in the proper direction, that is downwards, for readdressing the balance. The vertical fins so largely employed in monoplanes have the same effect as regards lateral disturbance. In all cases the object is to prevent the aeroplane from being unduly influenced by sudden wind gusts, and as a consequence to render manipulation by the aviator easier.

Rudder.—The aeroplane is steered laterally by a rudder in the same way as a ship is steered by its rudder. The rudder is supported by the extension to the framework, which carries the tail, and is placed, in biplanes and most monoplanes, well behind the main planes. Several different designs of rudder are employed. For complete control the rudder should be of such a size that it will overcome the action of the "warp" on the planes if it so be desired.

Stability.—The condition which must be present in order to ensure stability is that all abnormal movements of the aeroplane must bring into existence forces tending to suppress the said movements. If, due to irregular air currents, the machine begins to pitch, forces must at once be brought into play which will tend to restore the horizontal position; or, if the machine begins to roll, forces must be created which tend to restore the machine to the condition of an even keel. As the deviation from the normal position becomes greater, the righting forces must increase in magnitude so that they not only act to suppress the movements referred to, but act to right the machine whenever the disturbing influence is removed. The lateral stability is increased by inclining the planes on each side of the machine at a dihedral angle, as shown in Fig. 17, a course almost invariably adopted in monoplanes.

FIG. 17.

Under normal conditions the machine would be proceeding on an even keel, as shown at *a*, but owing to gusts or eddies it might be caused to heel over as at *b*. It will be evident that the air pressure now acts more directly on the right-hand plane than on the left-hand one, or in other words, that the lifting force on the horizontal plane is greater than on the inclined plane. Due to this excess of pressure on one side there is established, consequent on the heeling

over of the machine, a force tending to restore it to the position a, which will eventually right it into this position.

The above illustrates generally the principles upon which stability depends, and though every machine must be constructed on lines which enable these principles to be adopted, the merely automatic adjustment resulting has to be supplemented by manipulation on the part of the aviator. To maintain equilibrium under the ever-changing wind conditions, it is advisable that the relative inclination of the main planes should be capable of variation. Means are accordingly provided for altering the angles of the right and left hand planes relatively to each other. In some machines this is effected by making part of the planes flexible and simultaneously warping or bending this part upwards on one side of the machine and downwards on the other. In other cases supplementary planes on opposite sides of the machine are employed, one being inclined upwards while the other is simultaneously inclined downwards. In either case the result is in effect to alter the relative angles of the right and left planes, so as to maintain stability under all conditions which may arise.

Natural longitudinal stability also depends on a dihedral angle, obtained by setting the main planes and the leading or tail plane at different angles to the line of flight. If the supplementary plane is carried in advance of the main planes, it must be "superloaded," *i.e.*, it must be set at a greater angle of incidence than that of the main planes, and so must carry more weight per unit of area. If the supplementary plane is carried in the form of a tail, it must be set at a less angle than the main planes, the rule being obviously that the dihedral angle must open upwards. It is for this reason that the "non-lifting" tail is now becoming so popular. Aeroplanes which have no fixed leading or tail plane, have no natural longitudinal stability, but are dependent on the skill of the pilot for their balance. At the same time they are more responsive to the controls. A small load is often carried by the tail plane in order to increase the "liveliness" of the aeroplane on the controls. A mathematical explanation of the longitudinal dihedral angle will be found on p. 34.

On a machine with a dihedral angle between the wings there is a tendency to heel over when struck by a sideways gust. This is counteracted by placing a vertical fin below the wings, of an area at least as great as the horizontally projected area of one of the wings. This is often provided by the covered-in fuselage on a monoplane.

Another reason for using a vertical fin is to enable the machine to recover from a "side-slip." If the aeroplane commences to slide sideways through the air, some means of bringing the tail up and the front down must be provided, so as to convert the side-slip into a "nose-dive," and permit the pilot to regain control. If a vertical surface is provided aft of the centre of pressure on the planes, this will result automatically, and, provided the machine was at a suf-

ficient height at the beginning of the slip, it will regain its natural gliding position.

A vertical surface is also useful in giving something in the nature of a fulcrum for the rudder to work against.

The Cambered Plane.—The lift of a cambered plane may be found as follows :—

Let α be the "angle of trail."
- d ,, the "sweep."
- l ,, length of surface perpendicular to the direction of flight.
- A ,, total area.
- V ,, flight speed in feet per second.
- L ,, lift.
- b ,, chord.
- δ ,, weight of unit volume of air.

$$L = \frac{\delta}{g} ld V^2 \tan \alpha.$$

If d is assumed to be proportional to the chord b,

$$L = \frac{\delta}{g} AV^2 \tan \alpha.$$

For any particular plane this may be expressed as

$$L = KAV^2,$$

where K is a constant including tan α, and also the factor for converting V in feet per second to a corresponding value in miles per hour. It is difficult to give a trustworthy value to K, but it is usually somewhere in the neighbourhood of ·0075. Account must be taken of the fact that in a monoplane some of the lifting surface works in the propeller blast, and this must be allowed for in taking a value for V.

Sections of the planes used by various makers will be found in Fig. 19. Messrs Short Brothers have given the following sizes as representing good practice :—

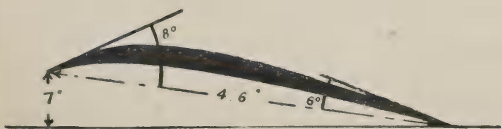


FIG. 18.

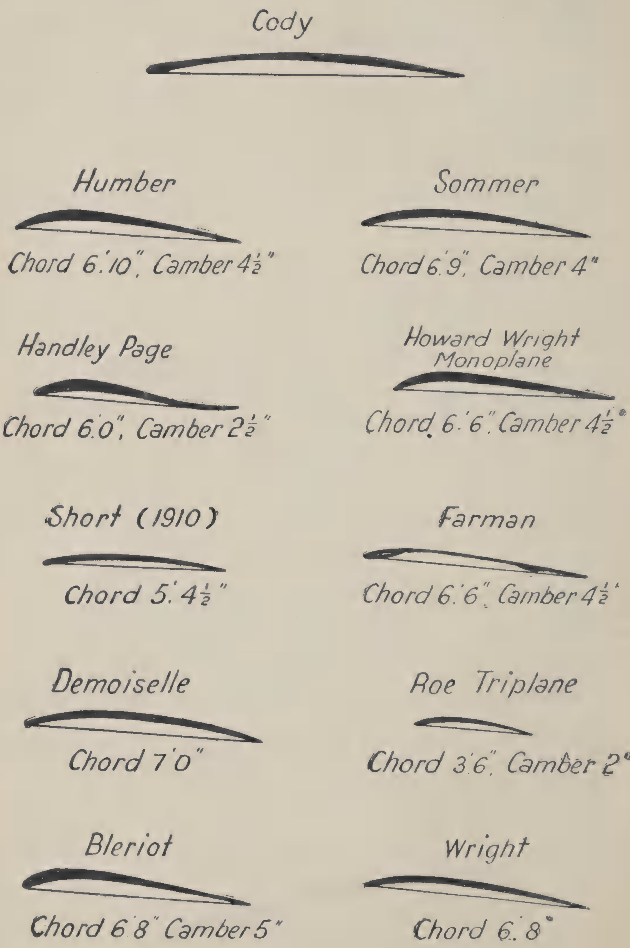


FIG. 19.—Sections of Planes on Actual Machines.

Equilibrium of an Aeroplane in Flight.—The forces acting on an aeroplane in flight are as follows :—

1. The weight, acting through the centre of gravity of the machine.

2. The lift, acting through the centre of pressure.

3. The thrust, acting through the centre of thrust, *i.e.*, the axis of the propeller.

4. The resistance, acting through the centre of resistance.

The ideal condition is that the lines of action of all these forces should meet in a point, but this is not always attainable. If it is not fulfilled, the sum of the moments of the forces taken about any point on the aeroplane must be equal to zero.

It is desirable for several reasons that the "moment of inertia" of the machine should be small; in other words the chief masses should be placed as close together as possible.

Lateral Control.—This can be obtained in four ways: by the use of ailerons, balancing flaps, wing-warping, and balancing planes.

The effect of all these is the same; the advantages and disadvantages are as follows :—

Ailerons (supplementary planes fitted as extensions to the main planes, and capable of being moved about a horizontal axis).—These are inefficient, and rather troublesome to arrange. They can be partially balanced.

Balancing Flaps.—Cannot be balanced, and are, therefore, hard to work in windy weather. Efficient and easy to fit.

Wing Warping.—Efficient and easy to work. Necessitates special wing construction, and may ultimately weaken the wing through "fatigue" of the material.

Balancing Planes.—Inefficient if fitted between the wings of a biplane. They have the advantage that the head resistance of one side of the machine relatively to the other is not altered, if the balancing planes on opposite sides are made to work simultaneously in opposite directions.

Stability by Longitudinal Dihedral Angle

The sketch shows an exaggerated condition in order to add clearness to the figure.

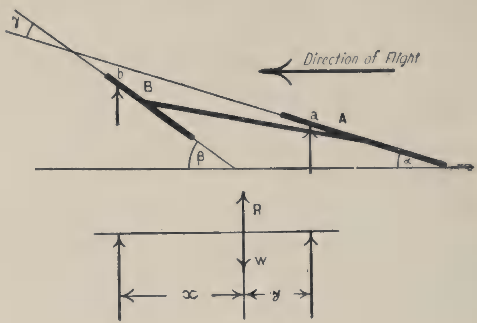


FIG. 20.

α. Angle of incidence of rear plane (A).
β. ,, ,, leading plane (B).
a. Centre of pressure on rear plane (A).
b. ,, ,, leading plane (B).
γ. Angle between leading and rear planes.

Since α and β are small, the pressures per square foot are proportional to α and β.

Total pressures are proportional to A and B.

Resultant pressure $= R = A\alpha + B\beta$, and acts at a point such that—

$$\frac{y}{x} = \frac{B\beta}{A\alpha} = \frac{B(\alpha+\gamma)}{A\alpha} = \frac{B}{A}\left[1 + \frac{\gamma}{\alpha}\right].$$

Now let us suppose that the aeroplane pitches, so that α and β are reduced.

Then $\frac{\gamma}{\alpha}$ will be increased, *i.e.*, $\frac{y}{x}$ is increased.

This will mean that the resultant pressure moves forward, producing a righting effect on the machine considered as a whole. The same argument may be applied if the effect of a backward "pitch" of the aeroplane is considered.

The above proof is due to Mr T. W. K. Clarke.

Soaring.—The question of "soaring" has recently been brought into prominence by the experiments of the Wright brothers.

"Soaring" has been defined as "gliding in an upward current of air," *i.e.*, a current such that the natural downward fall of a glider is counteracted by the upward trend of the wind. It has long been

known to be possible, and it may be taken that the following are the requisites for its performance :—

1. Perfect control of the aeroplane.
2. A very low gliding angle, obtained by diminution of head resistance. The gliding angle must probably be reduced to at least 5° or 4°.
3. A suitable locality for practice.
4. An initial forward velocity is necessary before soaring can be commenced.
5. It is probable that when actually soaring the angle of incidence of the machine will be *negative* and not less than 3°.

It will be noticed that once a sufficient altitude has been obtained, progress may be made in any desired direction by gliding downwards.

Parachutes.—It may be pointed out that the many suggestions as to the use of parachutes on aeroplanes do not take account of the fact that in case of an engine stoppage or the like, the aeroplane itself acts as efficiently as a parachute, and has the additional advantage of allowing the landing ground to be chosen.

The area allowed in a parachute should be about 4 sq. ft. per lb. weight to be supported; a hole must be made in the centre of its surface to establish a stable flow of air, and thus prevent violent oscillations and a possible overturn.

BIRD FLIGHT

Wing Surface in Insects and Birds (De Lucy)

Name.	Square Feet of Wing Surface for Each Lb. of Weight.
Insects.	
Gnat	48·77
Ladybird	22·06
Dragon fly	21·6
Daddy-long-legs	14·82
Bee	5·22
Bluebottle fly	5·6
Drone	5·0
Cockchafer	5·16
Stag beetle (female)	4·65
,, (male)	3·75
Birds.	
Swallow	4·87
Sparrow	2·72
Turtle dove	2·13
Pigeon	1·27
Stork	0·97
Vulture	0·82
Crane	0·41

FLIGHT OF INSECTS AND BIRDS (Marey)

Name.	Beats of Wing per Second.	Hundredths of a Second for Each.
Insects.		
Common fly	330	·31
Drone	240	4·2
Bee	190	5·3
Wasp	110	9·1
Moth	72	1·4
Dragon fly	28	3·6
Butterfly	9	11·1
Birds.		
Sparrow	13	7·7
Wild duck	9	11·1
Pigeon	8	12·5
Screech owl	5	20·0
Buzzard	3	33·3

WING SURFACE IN BIRDS ("FLIGHT")

Bird.	Weight.		Surface.	Span.	Sq. Ft. of Wing Surface.
	Lbs.	Oz.	Sq. Ft.	Ft.	Per Lb.
Golden eagle	7	0	6	8	0·86
Egyptian vulture	4	0	4	$4\frac{1}{2}$	1·0
Sea eagle	7	0	6	8	0·86
Common kite	1	8	3	$4\frac{1}{2}$	1·7
Osprey	3	0	3	$4\frac{1}{2}$	1·0
Heron	3	8	$3\frac{1}{3}$	$4\frac{1}{2}$	0·95
Goshawk	0	10	1	$2\frac{1}{4}$	1·6
Sparrow hawk	0	6	$0\frac{3}{4}$	$1\frac{3}{4}$	2
Stork	5	0	4	$6\frac{1}{2}$	1·3

The above are all soaring birds, and it will be seen that their wing surface varies in the region of 1 to 2 sq. ft. per lb. of their weight.

Speed of Wing Movement in Birds

Name of Bird.	Time taken in Hundredths of a Second.		
	For Beat (downwards).	For Back Stroke (upwards).	For Beat and Back Stroke Complete.
Wild duck - - -	6·6	5·0	11·6
Pigeon - - - -	8·5	4·0	12·5
Buzzard - - -	20·0	12·5	32·5

A series of papers by Dr Hankin embodying the results of an enormous amount of observation, appeared in *Flight* during the latter half of 1911, and should be consulted for information as to the actual movements of the wings of birds when flying.

Propellers

Drzewiecki's Method.—The quantities required to be known are the speed of the machine (V); the B.H.P. of the motor (H.P.); the speed of the propeller in revolutions per second (n).

1. Pitch constant $= \frac{V}{2\pi n} = M$.
2. Diameter $= 10M = D$.
3. Specific width of blade $= {\cdot}75M = w$.

The effective portion of the blades should start at a point distant $\frac{1}{2}$M from the boss.

To construct the propeller, a drawing is made as under :—

Mark off OB equal to M.

On OY, perpendicular to OB, mark off distances equal to $\frac{1}{2}$M, M, 2M, 3M, 5M, thus obtaining the points C, D, E, F, G.

Join BC, BD, BE, BF, BG.

Mark off CH, DJ, EK, FL, GM equal to $\frac{1}{4}w$.

Draw horizontal lines through H, J, K, L, M.

Mark off CN, DP, EQ, FR, GS equal to $\frac{3}{4}w$.

Draw horizontal lines through N, P, Q, R, S.

Draw a vertical line at any convenient distance from OY to complete the shaded figures, which then form a series of templates to which the propeller can be constructed.

These templates are cut out in thin wood, and curved to the radii OC, OD, etc., respectively. They are then fixed on a plane board so that they are normal to the board and to the axis on the board corresponding to OY, at distances OC, OD, OE, etc.

The upper surfaces of the templates then form portions of the continuous curve to which the propeller blade must be cut, the point corresponding to O being the centre of rotation.

When the blade is made to these templates, its advancing side should be slightly hollowed in order to accelerate the air gradually, on the same principle that an aerofoil is cambered.

The well-known "Normale" propeller is made to M. Drzewiecki's designs on the above principles.

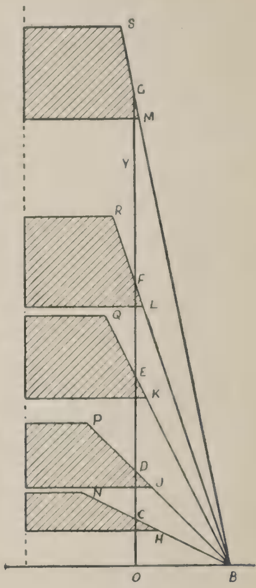


FIG. 21.

Testing Propellers.—It must be remembered that the thrust of a propeller when it is stationary is not the same as that obtained when it is mounted on a machine travelling through the air. Tests should be carried out under conditions similar to those under which the propeller is intended to work.

The whirling table at Messrs Vickers' establishment at Barrow is announced to be available for this purpose. A smaller table is also available at the National Physical Laboratory. The following are the particulars of the apparatus as installed at Messrs Vickers' works :—

Radius at which propeller is mounted, 110 feet.

Thrust can be measured to 1 per cent., up to 500 lbs.

Revolutions of propeller can be varied from 500 to 1,000.

Flight speed up to 70 miles per hour.

Particulars of Propellers used on Dirigibles

Year.	Name of Dirigible.	Number	Diameter.		Revolutions per Minute.	Number of Blades.	Drive.	Engines.	
			Metres.	Feet.				Horse-power.	Revolutions per Minute.
1783	Meusnier	3	...	...	...	...	...	...	...
1858	Giffard, No. 1	1	3·4	11·2	110	3	Direct	3·0	300
1855	,, ,, 2	1	3·4	11·2	110	3	,,	3·0	300
1870	Dupuy de Lôme	1	9·0	29·5	25	4	,,	3·0	25
1872	Hähnlein	1	4·6	15·1	90	4	,,	3·6	90
1883	Tissandier	1	3·0	9·8	120	2	Gear	1·5	120
1884	Renard-Krebs	1	7·0	23·0	46	2	,,	8·5	3,600
1897	Schwarz	3	2·75	9·2	480	2	Belt	12·0	480
	With Petrol Engine Drive.								
1898	Santos Dumont, No. 1	1	1·0	3·28	1,200	2	Direct	1·75	1,200
1899	,, ,, 3	1	0·8	2·6	1,200	2	,,	2·5	1,200
1900	,, ,, 4	1	4·0	13·1	100	2	Gear	7·0	...
1900	,, ,, 5	1	4·0	13·1	140 / 200	2	,,	16·0	1,600
1900	Zeppelin, No. 1	4	1·15	3·8	1,100	4 / 3	Bevel / ,,	14·7 × 2	700
1901	Santos Dumont, No. 6	1	4·0	13·1	200	2	Gear	16·0	1,200
1901	,, ,, 7	1	...	...	...	2	,,	60·0	?
1901	,, ,, 9	1	3·0	9·8	200	2	,,	3·0	1,100
1901	,, ,, 10	1	...	...	...	2	,,	20·0	1,500

PARTICULARS OF PROPELLERS USED ON DIRIGIBLES—*Continued.*

Year.	Name of Dirigible.	Number	Diameter. Metres.	Diameter. Feet.	Revolutions per Minute.	Number of Blades.	Drive.	Engines. Horse-power.	Engines. Revolutions per Minute.
1901	Deutsch de la Meurthe	1	7·5	24·6	120	2	,,	60·0	900
1901	Rozé	2 2	3·4 3·4	11·2 11·2	300	1 1	Bevel ,,	20·0	?
1901	Bradsky	1	4·0	13·1	350	2	Friction	16·0	...
1902	Severo	1 1	6·0 4·0	19·7 13·1	150	2	Chain	24·0 16·0	?
1902	Lebaudy (Julliot)	2	2·44	8·0	800 1,100	2	Bevel	40·0	1,200
1902	Spencer	1	3·0	9·8	900	2	Gear	23·5	...
1904	Julliot, "Patrie"	2	2·5	8·2	1,100	2	Bevel	70·0	1,000
1905	Zeppelin, No. 2	4	...	...	900	3	,,	85 × 2	...
1906	"Ville de Paris"	1	6·0	19·7	180	2	,,	70·0	900
1906	Comte de la Vaulx	1	3·0	9·8	900	2	,,	16·0	1,500
1906	Parseval, No. 1	1	3·5	11·5	1,000	4	Chain	90·0	1,000
1907	Santos Dumont, No. 16	2	1·15	3·8	?	2	Direct	7 × 2	?
1908	Zeppelin, No. 3	4	...	...	900	3	Bevel	110 × 2	1,100
1908	,, ,, 4	4	...	...	900	3	,,	114 × 2	1,100
1908	Julliot, "La Republique"	2	...	...	700	2	,,	55·0	...
1908	Malécot	1	3·8	12·4	400	2	,,	30·0	...
1908	Clement-Bayard	1	5·0	16·4	380	2	Direct	105·0	380
1908	Parseval, No. 2	1	3·5	11·5	250 300	4	Bevel	114·0	1,100
1908	Major Gross	2	...	...	...	3	Chain and bevel	...	...

DIVISION III

STRUCTURAL MATERIALS

AEROPLANE STRUCTURE

WHEN the loading, propeller thrust, and weight of a machine have been determined, the design of many of its parts is a matter of applying the appropriate engineering formula.

Considering first the main wing spars, in a monoplane these are in a somewhat unusual state of stress, being under a distributed bending load due to the lift of the plane, another bending load at right angles to the lift, due to the drift and head resistance of the planes, and a direct compression due to the load on the stay wires. The investigation is somewhat complicated, but the resulting formula will be found on p. 68. As the load on the deck of an aeroplane is suddenly removed when the machine touches the ground, half the ordinary working stress for a live load should be adopted for wing members. For the ordinary type of biplane, the spars in the upper and lower decks are generally connected up by struts and wire stays to form a lattice girder, and the stresses must be considered from this standpoint. For a biplane, the ideal arrangement is probably somewhat on the lines of the Bréguet machine, with single wing spars placed at the normal position of the centre of pressure on the planes, and united by members which have little else to carry than a direct compressive or tensile load. These members should be designed to take a compressive load equal to the normal tensile load, on account of the stress reversal on landing and on starting a steep *vol plané*.

The ribs on which the fabric is stretched are beams supported by the main spars and subjected to the distributed load of the air pressure on the plane.

The fuselage is a beam, and may be considered as supported by the air pressure at the points of junction of the wing and lifting tail spars, and loaded by the weights of the engine, pilot, and landing chassis, when the machine is in the air; and as supported by the landing chassis and tail skid, and loaded by the weights of the engine, decks, and pilot, when the machine is on the ground, the greater stresses being used in fixing the sizes of the members.

The correct sizes of the landing chassis are a matter of experience, since the stresses caused by a violent atterrissage can only be estimated, and not accurately determined.

Notes on Materials

Timber.—The strength of timber is affected by various circumstances, such as the season of felling, the seasoning, and the portion of the tree from which the specimen is cut. The soundest part of a plank is that between the heartwood and the sapwood. Hollow spars are made by binding with fabric and waterproofing with glue.

Ash is very flexible, but extremely tough, and resists sudden stresses very well. It is suitable for large members where great strength is required.

Bamboo is liable to split in diameters of 2 in. and over. It is very light, strong, and resilient, and has been used by several well-known constructors. Small rods up to $\frac{3}{4}$ in. diameter can be bent over a spirit lamp; they should be previously soaked in hot water. Larger rods may be filled with sand and soaked in boiling water until they give at the part required. They should be left on a former until quite dry, when the sand can be shaken out; the former should be given a slightly sharper curve than is required, as the bend "goes back" to some extent when dry. Joints may be made with a long plugged splice well glued up and wound externally with two diagonal layers of tape, the whole being again brushed with glue. Bamboos are strengthened by being wound with fine cord halfway between each pair of knots.

Beech is strong, close-grained, and very tough. It is not durable when exposed to the weather.

Birch is a strong, close-grained wood with a high resistance to splitting.

Cedar stands exposure well, and has been used as a veneer to cover monoplane bodies.

Elm is durable, but very liable to warp. It is tough, stiff, and strong, and is not split by tacks or small screws.

Firwoods work easily, are straight in fibre, and strong under all stresses but shearing. The *pines*, among the best of which is the *red pine* or *Memel deal*, vary widely, but the higher qualities are light and strong. The *white fir* or *Baltic spruce* is sometimes known as *deal*, and is of very fair quality, but the best of the firwoods is the *Canadian spruce*; this is not easily obtained in sound pieces in lengths of much above 15 ft. Spruce is very largely used in aeroplane construction; it is light, strong, stiff, and is not liable to warp. The ends should be protected, as it splits very easily.

Hemlock is an extremely light wood, and is fairly strong.

Hickory is an excellent wood, strong, tough, and resistant to splitting. It is not very durable unless varnished. Used in the original Wright machine.

Larch, although strong, is hard to work and liable to warp when exposed.

Mahogany is easily worked, but rather liable to split. The Spanish variety is stronger but heavier than the Honduras; neither stands exposure well.

Maple is light and resistant to splitting.

Oak is extremely durable and very strong, but expensive and heavy.

Poplar is durable, tough, and exceptionally light.

Teak is of compact structure, uniform quality, and great durability; it is much used in general engineering and shipbuilding.

Walnut is light and strong, but rather brittle.

Aluminium Alloys.—The softness and weakness of pure aluminium have led to the introduction of many alloys in which aluminium is the base, and is combined with copper, nickel, zinc, or magnesium, or with more than one of these metals. A very complete series of tests on various alloys is now in progress at the National Physical Laboratory, and the final results when published should prove invaluable.

The following table gives the results of a series of experiments carried out by Dr Rosenhain at the Laboratory on four typical alloys, as compared with pure aluminium :—

Material.		Condition.	Ultimate Strength.	Elongation on 2 in.
	Per Cent.		Tons per Sq. In.	Per Cent.
Aluminium	100	Chill castings	5·2	37·0
		Hot-rolled	7·2	30·5
		Cold-drawn	8·7	19·5
Aluminium	97·23	Chill castings	8·6	10·5
Copper	2·77	Hot-rolled	16·6	16·0
		Cold-drawn	17·8	9·5
Aluminium	96·24	Chill castings	9·6	10·5
Copper	3·76	Hot-rolled	17·0	21·0
		Cold-drawn	20·0	17·5
Aluminium	96·0	Chill castings	9·06	5·0
Copper	2·06	Hot-rolled	17·04	16·0
Manganese	1·94	Cold-drawn	18·32	6·0
Aluminium	96·17	Chill castings	12·05	13·5
Copper	2·89	Hot-rolled	16·5	15·0
Manganese	0·94			

The modulus of elasticity of the alloys in the foregoing table is of the order of 10×10^6 lbs. per square inch, and the density approximately 2·7.

Magnalium is an alloy of aluminium and magnesium, the proportion of the latter varying from 3 to 10 per cent. Specific gravity, 2·5. Can be cast, welded, soldered, forged, etc.; is claimed to be twice to two and a half times as strong as aluminium. Rather expensive, but can be obtained in convenient form as sheet, from 0·1 to 5 mm. thickness; wire, from 0·1 to 10 mm. diameter; and tube, 10 to 100 mm. diameter and 1 to 5 mm. thick; as well as castings and bars. Manufactured by the German Magnalium-Gesellschaft.

Duralumin contains over 90 per cent. of aluminium. Specific gravity, 2·8; melting point, 650° C. Properties vary with treatment: can be obtained with an ultimate tensile strength of 25 tons per square inch, and an extension of 20 per cent. in 2 in. Is unaffected by mercury, and can be obtained as plates, bars, screws, forgings, stampings, tube, or wire. Manufactured by the Electric and Ordnance Accessories Company.

Aluman contains 88 per cent. aluminium, 10 per cent. zinc, and 2 per cent. copper. Stated to be very strong, and can be readily forged and milled, but is rather heavy.

Macadamite is composed of 72 per cent. aluminium, 24 per cent. zinc, and 4 per cent. copper. Tensile strength stated as 20 tons per square inch, but probably is not ductile and stands shocks badly. Specific gravity comparatively high.

Nickel-Aluminium.—This alloy is stated by its manufacturers to have an ultimate tensile strength, as castings, from 18,000 to 28,000 lbs.; as plates, from 35,000 to 50,000 lbs., with an extension of 10 per cent. on 2 in.; as bars, from 30,000 to 45,000 lbs. Manufactured by the Pittsburgh Reduction Company. Specific gravity, 2·9.

Argentalium.—Specific gravity about 2·9; contains antimony.

Chromaluminum is composed of aluminium, chromium, and other metals. Specific gravity, 2·9. Stated to be one of the strongest light alloys.

Wolframium, or **Wolframinium,** contains aluminium, 98·04 per cent.; antimony, 1·442 per cent.; copper, 0·357 per cent.; tungsten, 0·038 per cent.; and tin, 0·015 per cent. Density the same as pure

aluminium (2·6). Readily worked. Tensile strength, hard drawn, 23 tons per square inch ; annealed, 16 tons per square inch, with an extension of 15 to 24 per cent. in 2 in. This alloy has been used in the construction of the Zeppelin airships.

Clarus alloy. Can be obtained as castings, tube, sheet, or wire. Tensile strength, 17 tons per square inch in the form of tubes, or 40,000 lbs. per square inch in the form of wire. Manufactured by Gabriel & Co., Birmingham.

Partinium (Victoria Aluminium).—Composition varies, but contains small quantities of copper and zinc. Best qualities have a tensile strength of 16 tons per square inch, with an extension of 10 to 12 per cent. in 2 in. Casts well, and is used for crank cases, etc.

Various Materials

Fabric Varnish.—Two or three kinds have been recently introduced to the English market. **Shellac** will give a smooth and quick-drying surface.

Spar Varnish has waterproof properties.

Aluminium Paint is very inelastic, and if applied to members likely to give, will show cracking by fine black lines on its surface.

Catgut and **Rawhide** stretch when wet and shrink when dry ; they have been used for binding the ends of spars. **Silk cord**, which is extremely strong, has been used for the same purpose.

STRENGTH AND WEIGHT OF MATERIALS

Note.—"Transverse strength" $= \frac{\text{Modulus of rupture}}{6}$

METALS

	Specific Gravity.	Weight of a Cubic Foot.	Weight of a Cubic Inch.	Tensile Strength per Square Inch.	Crushing Weight per Square Inch.	Transverse Strength.
		Lbs.	Lbs.	Tons.	Tons.	Tons.
Aluminium, sheet	2·67	166·6	·096	...	...	...
,, cast	2·56	159·8	·092	...	...	...
Antimony, cast	6·72	419·5	·242	...	...	...
Copper bolts	8·85	552·4	·318	17·0	...	...
,, cast	8·607	537·3	·31	8·4	...	...
,, sheet	8·78	548·1	·316	13·4	...	...
,, wire	8·9	555·0	·32	26·0	...	...
Iron, cast, from	7·0	437·0	·252	6·0	36·0	2·0
,, ,, to	7·6	474·4	·273	13·0	64·0	3·4
,, ,, average	7·23	451·0	·26	7·3	48·0	2·6
,, wrought, from	7·6	474·4	·273	16·0	16·0	3·0
,, ,, to	7·8	486·9	·281	29·0	18·0	5·5
,, ,, average	7·78	485·6	·28	22·0	16·9	3·8
,, wire	...	...	...	40·0	...	...
Mercury	13·596	848·75	·489	...	...	...
Steel	8·0	499·0	·288	52·0	150·0	...
,, plates	...	...	...	35·0	90·0	...
Tin, cast	7·291	455·1	·262	2·0	6·7	...
Zinc, cast	7·0	437·0	·252	3·3	...	...

ALLOYS

		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Aluman	2·95	184·0	·106	42,700	...	...
Aluminium bronze (90 per cent. copper)	7·68	481·0	·276	92,400	129,000	...
Chrome aluminium	2·95	184·0	·106	64,000	...	...
Magnalium	2·44	152·0	·088	41,000 to 64,000	...	...
Nickel aluminium	2·95	184·0	·106	57,000	...	...
Partinium	2·85	178·0	·103	21,300	...	...
Brass, cast	8·4	524·37	·3	18,000	...	...
,, sheet	8·44	526·86	·301	27,000	...	...
,, wire	8·54	533·109	·307	49,000	...	...
Gold (standard)	17·724	1,106·42	·638	...	...	...
Gun-metal, 10 copper, 1 tin	8·464	528·36	·306	46,000	...	...
White metal (Babbett)	7·31	456·32	·263	...	...	...

WOOD

Acacia, from	·71	44	·025	16,000	...	1,867
,, to	·79	49	·028	...	...	...
Alder	·80	50	·029	9,500	6,700	...
Ash	·69	43	·025	12,000	8,600	2,000
,,	·76	47	·027	17,000	9,300	3,000
Bamboo	·40	25	·015	39,000	...	...
Beech, from	·69	43	·025	11,000	7,700	1,500
,, to	·696	43	·025	12,000	9,300	2,000
Birch	·711	44	·026	15,000	3,300	1,900
,,	·730	45	·026	...	6,000	1,930
Box	1·28	80	·046	20,000	10,300	2,445

STRENGTH AND WEIGHT OF MATERIALS—*Continued*

Wood—*Continued*

	Specific Gravity.	Weight of a Cubic Foot.	Weight of a Cubic Inch.	Tensile Strength per Square Inch.	Crushing Weight per Square Inch.	Transverse Strength.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Cedar, West Indian - -	·748	47	·026	5,000	5,700	1,443
,, American - -	·554	35	·020	...	...	766
,, Lebanon - - -	·486	30	·017	11,000	5,800	1,300
Chestnut - - - -	·606	38	·022	12,000	4,500	1,770
Cork - - - - -	·240	15	·008	...	...	..
Elm, English - - -	·553	34	·02	13,200	10,300	782
,, ,, - - -	·579	36	·021	14,000	...	1,100
,, Canadian - - -	·725	45	·026	...	...	1,920
Fir, Larch - - - -	·543	34	·019	8,900	3,200	1,330
,, ,, - - - - -	·556	35	·02	10,200	5,500	1,660
,, American white spruce	·543	34	·019	10,000	8,500	...
,, California spruce - -	...	...	...	12,000 to 14,000	4,500 to 6,000	...
,, Norway spruce - -	·508	32	·018	5,000 to 12,500	...	...
,, Riga - - - -	·753	47	·027	9,500	...	...
,, Memel - - - -	·546	34	·019	9,500	...	...
,, Scotch - - - -	·528	33	·018	7,100	...	...
,, Christiania deal - -	·590	37	·021	12,400	5,800	...
Hickory - - - -	·690	43	·025	12,000	9,000	2,400

Hornbeam	·76	47	·027	20,000	4,600	...
Ironwood	1·15	71	·041	...	...	3,000
Jackwood	·67	42	·024	...	...	1,830
Lancewood	·725	45	·026	12,000	...	...
Lime	·564	35	·02	...	...	...
Lignum vitæ	·65 to 1·333	41 to 83	·024 to ·049	12,000	9,000	2,000
Mahogany, Nassau	·668	42	·024	...	...	1,719
,, Honduras	·560	35	·02	21,000	8,000	1,910
,, Spanish	·852	53	·031	12,000	8,200	1,300
Maple	·675	42	·025	10,600	...	1,694
Oak, African	·988	62	·035	17,000	...	2,523
,, American, red	·85	53	·03	10,000	6,000	1,680
,, ,, white	·779	49	·028	10,000	...	...
,, English	·777	48	·028	10,000	6,400	1,600
,, ,,	·934	58	·034	19,000	10,000	1,690
Pine, red	·576	36	·021	12,000	5,400	1,200
,, ,,	·657	41	·024	14,000	7,500	1,530
,, white	·432	27	·015	...	...	1,229
,, ,,	·553	34	·02	...	...	...
,, Georgia yellow	·508	32	·018	20,000	5,300	1,185
,, Dantzic	·649	40	·023	8,000	5,400	1,426
,, Memel	·550	34	·02	...	...	...
,, ,,	·601	37	·021	...	...	...
,, Riga	·466	29	·017	...	...	...
,, Pitch	·654	41	·023	12,000	...	1,383
Poplar	·39	24	·014	6,500	7,500	1,600
Teak	·74	46	·026	8,000	12,000	2,110
,,	·86	54	·031	15,000	...	...
Sycamore	·604	38	·022	13,000	...	1,500
Walnut	·671	42	·024	9,000	9,000	1,600

STRENGTH AND WEIGHT OF MATERIALS—*Continued*

MISCELLANEOUS SUBSTANCES

Material.	Specific Gravity.	Weight of a Cubic Foot.	Weight of a Cubic Inch.	Tensile Strength per Square Inch.
		Lbs.	Lbs.	Lbs.
Glass, plate -	2·7	170	·10	2,700
Glue - - -	...	...	...	500-750
Gutta-percha -	0·98	61	·035	...
Hemp rope - -	1·3	84	...	6,800-17,000
Horn - - -	...	...	...	9,000
Indiarubber -	0·93	58	·034	330
Leather - -	...	...	...	3,000-5,000
Plaster of Paris -	0·81	50	·029	...
Rawhide - -	...	...	...	12,000
Silk - - -	1·62	101	·051	35,000-62,000
Whalebone - -	...	...	...	7,600

Aeroplane Fabrics or Coverings

Materials.—Up to the present the general practice has been to cover the planes of flying machines with a woven air-tight fabric, though suggestions have been made to the effect that vulcanised fibre, ebonite, celluloid, and aluminium sheets might be employed to advantage. The materials used for the fabrics now employed are silk, cotton, calico, and linen, a fine Egyptian cotton being especially favoured. Oiled Japanese silk, muslin, cotton, oil paper, and Chinese parchment have been used by Santos Dumont, Roe, and Blériot, but apparently these materials have not proved as suitable as a cotton fabric treated with rubber or varnish.

Description.—The ideal fabric must be tightly woven with a yarn of uniform strength, and with approximately the same number of yarns in warp and woof. The yarn should be unbleached and without dressing or finish. The finished material must be strong and have a skin resistance as low as possible. It should also be tough and difficult to tear. Unlike balloon cloths, there is no need for gas tightness in the case of fabrics used for aeroplanes. Usually the material for the latter is, at most, about half the weight of balloon material.

Warp, Woof or Weft.—In describing aeroplane cloths, the ordinary technical terms used by weavers are employed. The **Warp** is the yarn running lengthwise in the cloth, while the **Woof** or **Weft** is the yarn running across the cloth, which is woven into the warp by the shuttle.

Attachment.—To enable the planes to maintain their true shape under the forces to which they are subjected, the framework is strongly ribbed, and the cloth is stretched over the ribs and attached thereto. There are several ways of making this attachment. In the Antoinette machine, a strip of wood is laid on the cloth above the rib, and both strip and cloth are secured by small nails driven into the rib. On certain machines, such as the Voisin, Santos Dumont, Piffard, and others, the fabric is in part laced on—a very good method, as it allows for tightening or for easy replacement when necessary. A very usual method of attachment is by glue, rubber solution, or other suitable cement, in addition to upholsterers' nails.

In the Short-Wright aeroplane, the stabilisers consist of cloth stretched between two small spars. Also, on the tails of the Antoinette, Humber-Le Blon, and a few other aeroplanes, the cloth was laced on, and so stretched between the horizontal and vertical uprights. These are the only instances in which attempts have so far been made to attach the covering to an aeroplane in a fashion somewhat similar to that adopted on a ship, *i.e.*, without definite support, except at the ends or sides.

In putting the cloth on the framework, care must be taken to avoid contact with iron and steel portions, since owing to the rusting or corrosion of these parts the fabric will be caused to rot in those places.

In the case of a cloth treated with rubber, the rubber coated side is always placed outwards. Where the planes are warped, the fabric is so disposed that the weft lies parallel to the line of flexure, for when the yarn runs so, the cloth remains taut and does not wear out so soon. After placing the fabric on the planes it is the custom of some makers to varnish the surface in order to reduce skin friction as much as possible.

Maintenance.—If, in course of time, owing to wear and exposure, the air-tight coating shows a tendency to become porous, or to peel off in places, the air-tight property of the fabric may be restored by spreading with a paste made of ordinary flour and water. Paulhan has employed this method with success, though it can only be regarded as a temporary expedient. Some of the fabric makers suggest painting with a thin rubber solution, and then partially vulcanising with hot irons to restore the tightness. In the case of "Pegamoid," a special air-drying varnish is provided, which makes repairs a simple matter.

Weather-Proofing.—Various methods have been adopted for making aeroplane fabrics weather-proof. A coating of vulcanised rubber seems to be most usual, though celluloid, linseed oil, and other varnishes are holding their own. Coating with rubber gives a very soft and pliable cloth, but it is expensive, and if great care is not taken in the manufacture, its life is short. It is a matter of the highest importance that the rubber coating on an aeroplane

covering material should be absolutely vulcanised. A number of fabrics are on sale which are either practically unvulcanised, or only in a semi-vulcanised state. As is well known, unvulcanised rubber is influenced by all climatic conditions. For instance, extreme cold reduces it to a hard brittle state; while extreme heat will bring it to a sticky, tacky condition. In this state, it is naturally not air-tight, and is especially liable to destruction.

The reason that several manufacturers offer their fabrics with the rubber in an unvulcanised state is that cotton is liable to be made "tender" by vulcanisation, unless carried out under correct conditions. There are, as is generally known, several methods of vulcanisation, and every fabric requires to be differently treated according to its special nature.

The best test as to whether an aeroplane material is properly vulcanised or not is to rub the vulcanised surface with naphtha or benzine. If the coated surface after being rubbed in this way is perfectly dry, it may be taken that the rubber is thoroughly vulcanised. If it becomes tacky, it is a sign that it is raw and unvulcanised.

Effect of Exposure.—Exposure to light and air causes rubber to deteriorate. This is purely an oxidising effect hastened by the action of light. For this reason the outer layer of a balloon cloth is usually coated with red or chrome colouring pigment to lessen actinic action. As aeroplane cloths have to be much lighter and contain less rubber, dependence is placed upon proper vulcanisation rather than on the aid of coloured external coatings. The result of oxidisation is the formation of a resinous material soluble in acetone, whilst pure vulcanised rubber is insoluble. Thus, the difference in percentage of resins found in a rubber before and after a period of exposure is a figure representing the amount of oxidisation that has taken place. A sample of cloth should simply be exposed to light and tested after a definite period, as to the extract it contains compared to the original it contained. In making this test the percentage of free sulphur extracted by the acetone should be taken note of.

Quality of Rubber.—This is a matter of the greatest importance, and should be most carefully covered by analytical tests. Alcoholic potash and acetone tests will determine whether any substitutes, re-manufactured rubber, or cheap resinous rubbers are being used in the compounds.

Moisture Absorption.—A good balloon fabric, coated as it usually is with comparatively thick rubber on both sides, will not absorb more than 4 per cent. of its weight in moisture, when exposed for, say, twenty-four hours to an atmosphere saturated with water vapour. As aeroplane cloths are not so heavily coated with rubber, and also since they are so light, the moisture absorp-

tion in the case of a good cloth, weighing about 4½ oz. per square yard, is from 5½ to 11½ per cent. of the total weight of the sample.

Testing Fabrics.—There seems to be no uniform or standard method of testing aeroplane and dirigible balloon fabrics. Each maker apparently has different ideas on the subject, some of the ideas being, it may be remarked in passing, of a very rule-of-thumb order. Among those firms that have given attention to the carrying out of tests in a systematic manner is the North British Rubber Company. This company uses a Goodbrand & Hoope machine for testing the samples, which are made of a uniform width of 1 in. and large enough to suit the jaws of the machine, which are 7 in. apart. Continental practice seems to be based on the test of a strip 5 cm. (nearly 2 in.) wide and 18 cm. (nearly 7⅛ in.) long. Tests should only be made after the fabric has been coated with the material employed to make it air-tight, since the special treatment it has to undergo may influence to a considerable extent results obtained from the uncoated cotton.

If careful attention is not given to the manner of testing, results on similar samples may differ by as much as 15 per cent., hence it is important to see that the samples are cut quite parallel to the direction of warp or weft, and that the test strip is placed in the machine so that the stress in testing runs parallel with the direction of the lengthways yarns.

Inaccuracy in the cutting or in the placing of the samples in the machine is indicated by the samples in the low tests not breaking evenly across. The highest results are taken as correct where the fracture occurs simultaneously across the test piece.

The following tables give such particulars as are obtainable of the leading makes of aeroplane cloths.

PARTICULARS OF STANDARD FABRICS

North British

Description.	Distinguishing Mark.	Weight per Sq. Yd. in Oz.	Tensile Strength in Lbs. Warp. Per Yd.	Warp. Per Ft.	Warp. Per In.	Weft. Per Yd.	Weft. P. Ft.	Weft. Per In.	Width. In.	Moisture Absorption above Normal Hydration. P. Cent.
Single proofed	1	4½	2,160	720	60	2,070	690	57	36	9
Three-ply -	2	4½	3,000	1,000	83	2,400	800	66	36	11½
Double proofed	3	4¾	2,160	720	60	2,070	690	57	36	5½
Single ,,	4	2½	950	317	26	700	233	19	36	10
Single ,,	5	4½	2,880	960	80	2,340	780	65	36	12
Double ,,	6	4¾	2,880	960	80	2,340	780	65	36	6

Continental

Description.	Distinguishing Mark.	Weight per Sq. Yd. in Oz.	Tensile Strength in Lbs.						Width.	
			Warp.			Woof or Weft.				
			Per Metre.	Per Ft.	Per In.	Per Total Width.	Per Ft.	Per In.	Cm.	In.
Ecru, single proofed	118	4·5	1,600	456	38	1,600	456	38	104	42
Ecru, single proofed	109	4·5	1,800	516	43	2,200	636	53	104	42
Ecru, double proofed	110	4·5	1,800	516	43	2,200	636	53	104	42
Yellow, single proofed	111	4·5	1,800	516	43	2,200	636	53	104	42
Ecru, single proofed	100*a*	6·5	2,370	672	56	2,550	732	61	104 or 130	42 or 52
Ecru, double proofed	100*b*	6·5	2,370	672	56	2,550	732	61		

The lengths of the pieces vary from 30 to 75 m. ($27\frac{1}{3}$ to $68\frac{1}{4}$ yds) according to the fabric.

Hutchinson

Description.	Quality Mark.	Weight per Sq. Yd. in Oz.	Tensile Strength in Lbs.						Width. In.
			Warp.			Woof or Weft.			
			Per M.	Per Ft.	Per In.	Per Total Width	Per Ft.	Per In.	
Single proofed - -	1	$3\frac{7}{8}$	...	627	52	...	600	50	42
Double ,, - -	2	$5\frac{1}{8}$	...	613	51	...	533	44	42
Single ,, - -	3	$4\frac{1}{4}$	...	320	27	...	347	29	42
,, ,, - -	4	$2\frac{3}{8}$	...	400	33	...	347	29	48
Double ,, - -	5	$3\frac{1}{2}$	...	400	33	...	347	29	48
,, ,, - -	6	$4\frac{3}{8}$	...	627	52	...	400	33	48

Frankenburg

Description.	Quality Mark.	Weight per Sq. Yd. in Oz.	Tensile Strength in Lbs. Warp. Per M.	Warp. Per Ft.	Warp. Per In.	Woof or Weft. Per Total Width	Woof or Weft. Per Ft.	Woof or Weft. Per In.	Width. In.
			Test-piece, 9 by 7 in.						
Double proofed -	1	5·4	...	213	...	...	270	...	42
Single ,, (heavy)	2	3·6	...	127	...	...	106	...	42
Double ,, ,,	3	4·2	...	130	...	...	115	...	42
Single ,, (light) -	4	3·0	...	95	...	...	91	...	42
,, ,, ,, -	4	3·0	...	130	...	...	115	...	42
,, ,, (silk) -	5	2·0	...	120	...	...	75	...	42
,, ,, ,, -	6	3·0	...	156	...	...	132	...	42

Pegamoid

Description.	Distinguishing Mark.	Weight per Sq. Yd. in Oz.	Tensile Strength in Lbs. Warp. Per Yd.	Warp. P. Ft.	Warp. P. In.	Woof. Per Yd.	Woof. P. Ft.	Woof. P. In.	Width. In.
Single treated -	1	3·4	1,584	528	44	1,584	528	44	45
Double ,, -	2	4	1,656	552	46	1,656	552	46	45
Super double treated	3	4·5	1,800	600	50	1,764	588	49	45
"Aeroplatte" (Rogers Bros.)									
Special finish -	2	2¼	1,326	442	37	966	322	27	39-40
Proofed - -	18	2⅜	1,188	396	33	774	258	22	39-40
Special finish -	5	2¼	1,512	504	42	894	298	25	39-40
,, ,, -	13	2⅜	1,818	606	51	984	328	27	39-40
,, ,, -	6	2	1,650	550	46	1,272	424	35	39-40
Proofed - -	19	2½	1,716	572	48	966	322	27	39-40
,, - -	16	2¼	1,488	496	41	978	326	27	39-40
Special finish -	10	4⅖	2,322	774	65	2,388	796	66	39-40
Proofed - -	15	4½	2,034	678	57	1,992	664	55	39-40

Vulcanised Silk Fabric

(Scottish Aeroplane Fabric Company)

Distinguishing Number.	Weight per Sq. Yd. in Oz.	Tensile Strength in Lbs. Warp. Per Yd.	Warp. Per Ft.	Warp. P. In.	Woof. Per Yd.	Woof. Per Ft.	Woof. P. In.	Width.
7½	2¾	1,368	456	38	936	312	26	36
8½	2⅞	1,440	480	40	1,008	336	28	36
10	3⅛	1,584	528	44	1,080	360	30	36
12	3¼	2,016	672	56	1,224	408	34	36
1,065	4	3,816	1,272	106	2,016	672	56	25

Dunlop

Description.	Distinguishing Number.	Weight per Sq. Yd. in Oz.	Tensile Strength in Lbs. Warp. Per Yd.	Warp. Per Ft.	Warp. Per In.	Woof. Per Yd.	Woof. Per Ft.	Woof. Per In.	Width. In.
Single proofed	A1	3¼	1,585	528	44	1,997	666	56	43-44
Double ,,	A5	3½	1,585	528	44	1,997	666	56	43-44
Single ,,	A2	3¾	2,226	742	62	2,485	828	69	43-44
Double ,,	A6	4	2,226	742	62	2,485	828	69	43-44
Single ,,	A3	4½	2,640	880	73	3,200	1,067	89	43-44
Double ,,	A7	4¾	2,640	880	73	3,200	1,067	89	43-44
Single ,,	A4	5	3,172	1,057	88	3,415	1,138	95	43-44
Double ,,	A8	5¼	3,172	1,057	88	3,415	1,138	95	43-44

The above figures are taken from the results of tests carried out on Dunlop fabrics by the Manchester Chamber of Commerce.

Ramie Cloth

Distinguishing Mark.	Weight per Square Yard in Oz.	Tensile Strength in Lbs. Warp. Per Yd.	Warp. Per Ft.	Warp. Per In.	Woof. Per Yd.	Woof. Per Ft.	Woof. Per In.	Width. In.
1	3·63	3,888	1,296	108	2,736	912	76	36
3	3·21	3,888	1,296	108	2,736	912	76	36

Various Materials

Material.	Distinguishing Mark.	Weight per Square Yard in Oz.	Width, or Size of Sheet.	Remarks.
			In.	
Ponghee silk	...	2·84	...	Has been used in French Army.
Goldbeaters' skin	...	0·37	...	Average size of skin, 36 × 10 in.
Spinnaker canvas	...	4	36	Close mesh, not proofed, 1s. 6d. per yd. run.
Willesden canvas	Heavy E.W.D.	18·52	35	Proofed, 1s. 6½d. per yd. run.
,, ,,	J. 47	16	27	,, 1s. 2½d. per yd. run.
,, ,,	...	5·54	39	,, 1s. 3d. per yd. run.
,, ,,	...	13·33	27	,, 11d. per yd. run.
,, ,,	...	10·67	27	,, 10d. per yd. run.
Canvas-backed paper	...	6	36	24 S.W.G. thick, 1s. 2d. per yd. run.
Willesden paper,	B. 180			
1 ply -	B. 180	4·8	60	6½d. per yd. run.
2 ,, -	...	9·6	60	1s. 1d. per yd. run.
Aluminium gauze	...	5·4-3·6	...	Wire 14 mm. diameter.
Iron gauze -	...	from 13·5	...	... ...
Sheet steel -		7·05	...	0·3 mm. thick.
Vulcanised fibre	(Flexible)	15·75	66 × 42	$\frac{1}{64}$ in. thick } Can be moulded in hot water.
,, ,,	(Hard)	31·5	66 × 42	$\frac{1}{32}$,, ,,
,, ,,	,,	62·5	66 × 42	$\frac{1}{16}$,, ,,
Ebonite -	...	27	48 × 20	$\frac{1}{32}$,, ,,
Celluloid -	...	18	35 × 20, 52 × 23½, 55 × 24	·02 in. thick } Can be moulded in hot water. Can be obtained down to ·006 in. thick.
,, -	...	27·9		·03 ,, ,,
Aluminium sheets	...	14·4 lbs.	6 × 72, 24 × 72, 48 × 72	11 S.W.G. (·116 in.) thick.
		8·91 ,,		15 ,, (·072 ,,) ,,
,, ,,	...	3·98 ,,	6 × 72, 24 × 72, 36 × 72	21 ,, (·032 ,,) ,,
,, ,,	...	2·48 ,,		25 ,, (·020 ,,) ,,
,, ,,	...			

WEIGHT OF LIQUIDS

	Specific Gravity.	Weight of 1 Cub. Ft. (Lbs.)	Weight of 1 Cub. In. (Lbs.)
Water - - - -	1·00	62·425	·036
Acetic acid - - -	1·06	66	·038
Alcohol, absolute - -	0·792	49	·028
,, proof - -	0·916	57	·033
Benzene - - -	0·900	56	·033
Ether - - - -	0·716	45	·026
Glycerin - - -	1·260	79	·046
Hydrochloric acid, concentrated	1·20	75	·043
Iodine - - - -	8·72	544	·315
Linseed oil - - -	0·94	58	·034
Mercury - - -	13·60	849	·491
Nitric acid, concentrated	1·217	75	·044
Olive oil - - -	0·92	57	·033
Paraffin, American -	0·815	51	·029
,, Russian - -	0·825	52	·030
Petrol - - - -	0·70	44	·025
Petroleum, Penn., heavy	0·886	55	·032
,, Caucasian, heavy	0·938	59	·034
,, ,, light	0·884	55	·032
,, refuse - -	0·938	59	·034
Sea water - - -	1·027	64	·037
Sulphuric acid, concentrated	1·84	115	·066
Weight of Gases			
Carbonic acid - -	·00197	·123	·000071
Hydrogen - - -	·0000895	·0056	·0000032
Nitrogen - - -	·00125	·078	·000045
Oxygen - - - -	·00143	·089	·000051
Coal gas - - -	·0004	·034	·00002
Air - - - -	·001293	·08072	·00004655

MODULI OF ELASTICITY

(Millions of Pounds per Square Inch)

See p. 67.

Material.	E.	C.	K.
Aluminium, cast	12·0		...
,, sheet	13·0	3·4 to 4·8	...
,, wire	19·0		...
,, bronze (90 per cent. Al., 10 per cent. Cu)	18·0	...	...
Brass, cast	9·0		
,, rolled	12·5	5·0 to 5·5	15·3
,, wire	14·2		
Copper, cast	12·0		
,, rolled	15·0	5·6 to 6·7	17·1 to 24·4
,, wrought	16·0		
,, wire	17·0		
Delta-metal, cast	12·0	...	14·4
,, rolled	13·0	5·25	
Gold, drawn	12·0	4·0 to 5·6	...
Gun-metal	13·5	3·7	...
Iron, cast	17·0	5·0 to 7·6	14·1
,, wrought, bars	29·0	10·5	
,, ,, plates	26·0	9·5	21·0
,, ,, wire	25·0	...	
Lead	0·72	0·27	5·3
Magnalium	10·2	...	...
Phosphor bronze	14·0	5·3	...
Platinum	24·0	8·9 to 9·4	...
Silver	11·0	3·8	...
Steel, mild	30·0	11·0	
,, bars	29-42	13·0	
,, cast, tempered	36·0	14·0	
,, cast, untempered	30·0	12·0	21·6 to 26·7
,, tool	40·0	...	
,, wire	27·0	...	
,, piano wire	32·0	...	
Tin	4·6	2·2	...
Zinc	13·68	5·1 to 5·4	...

MODULI OF ELASTICITY—*Continued*

Material.	E.	C.	K.
Indiarubber	Varies	...	...
Silk	1·3	...	...
Slate	13·0	3·2	...
Leather	·025	...	...
Glass (plate)	8·0	3·3 to 3·9	5·8
Ice	8·5	...	...
Wood	...	0·1 to 0·17	...
Water	...	...	0·32
Alcohol	...	...	0·162
Ether	...	...	0·115
Carbon bisulphide	...	...	0·232
Glycerine	...	...	0·585
Petroleum	...	...	0·211
Mercury	...	...	7·850

TIMBERS

Timber.	E.	Timber.	E.
Ash	1·64	Mahogany, Spanish	1·4
Bamboo	3·2	Pine, pitch	1·90
Beech	1·345	,, red	1·85
Cedar	0·48	,, Georgia yellow	2·07
Deal, Memel	1·60	,, white	1·10
Elm	1·34	Sycamore	1·04
Fir, larch	1·074	Teak	2·40
,, spruce	1·6	Oak, European	1·42
Mahogany, Honduras	1·6		

SPECIFIC GRAVITIES AND MELTING POINTS

	Specific Gravity.	Weight per Cub. In. (Lbs.).	Melting Point. ° C.
Aluminium	2·60	·094	600
Antimony	6·70	·242	440
Bessemer soft steel	7·80	·282	1,450
Bismuth	9·80	·354	260
Brass	8·4	·300	800
Copper	8·91	·322	1,050
Iron (pure)	7·78	·282	1,500
Lead	11·4	·410	326
Magnesium	1·74	·063	...
Mercury	13·6	·490	−39
Nickel	8·9	·321	1,500
Platinum	21·2	·765	1,775
Silver	10·5	·379	950
Tin	7·3	·264	230
Zinc	7·1	·256	415
Potassium	0·865	·031	62·5
Sodium	0·98	·035	95·6
Manganese	7·2	·026	...
Sulphur	2·07	·075	114·5

WEIGHT AND VOLUME OF WATER AT DIFFERENT TEMPERATURES

Temperature. ° F.	Relative Volume.	Weight per Cubic Foot (Lbs.).	Weight per Gallon (Lbs.).
32·0	1·00000	62·418	10·0101
35·0	0·99993	62·422	10·0103
39·1	0·99989	62·425	10·0112
40·0	0·99989	62·425	10·0112
45·0	0·99993	62·422	10·0103
46·0	1·00000	62·418	10·0101
50·0	1·00015	62·409	10·0087
52·3	1·00029	62·400	10·0072
55	1·00038	62·394	10·0063
60	1·00074	62·392	10·0053
62	1·00101	62·355	10·0000
65	1·00119	62·344	9·9982
70	1·00160	62·313	9·9933
75	1·00239	62·275	9·9871

WEIGHT AND VOLUME OF WATER—*Continued.*

Temperature. ° F.	Relative Volume.	Weight per Cubic Foot (Lbs.).	Weight per Gallon (Lbs.).
80	1·00299	62·232	9·980
85	1·00379	62·182	9·972
90	1·00459	62·132	9·964
95	1·00554	62·074	9·955
100	1·00639	62·022	9·947
105	1·00739	61·960	9·937
110	1·00889	61·868	9·922
115	1·00989	61·807	9·913
120	1·01139	61·715	9·897
125	1·01239	61·654	9·887
130	1·01390	61·563	9·873
135	1·01539	61·472	9·859
140	1·01690	61·381	9·844
145	1·01839	61·291	9·829
150	1·01989	61·201	9·815
155	1·02164	61·096	9·799
160	1·02340	60·991	9·781
165	1·02589	60·843	9·757
170	1·02690	60·783	9·748
175	1·02906	60·665	9·728
180	1·03100	60·548	9·711
185	1·03300	60·430	9·691
190	1·03500	60·314	9·672
195	1·03700	60·198	9·654
200	1·03889	60·081	9·635
205	1·04140	59·930	9·611
210	1·04340	59·820	9·594
212	1·04660	59·640	9·565
250	1·06243	58·750	9·422
300	1·09563	56·970	9·136
400	1·15056	54·250	8·700
500	1·22005	51·160	8·204

COEFFICIENTS OF EXPANSION PER DEGREE F.

Aluminium, cast	$12{\cdot}3 \times 10^{-6}$	Iron, wrought	$6{\cdot}5 \times 10^{-6}$
Gold	$7{\cdot}8 \times 10^{-6}$	Steel	$6{\cdot}3 \times 10^{-6}$
Silver	$10{\cdot}7 \times 10^{-6}$	Brass, cast	$9{\cdot}5 \times 10^{-6}$
Platinum	$4{\cdot}7 \times 10^{-6}$	,, sheet	$10{\cdot}5 \times 10^{-6}$
Mercury	$33{\cdot}3 \times 10^{-6}$	Slate	$5{\cdot}7 \times 10^{-6}$
Lead	$15{\cdot}7 \times 10^{-6}$	Wood	$2{\cdot}7 \times 10^{-6}$
Tin	$11{\cdot}6 \times 10^{-6}$	Porcelain	$2{\cdot}0 \times 10^{-6}$
Iron, cast	$5{\cdot}5 \times 10^{-6}$	Ebonite	$42{\cdot}7 \times 10^{-6}$

STEEL STAY WIRE

Diameter in Decimals of Inch.	Diameter in Mm.	Number of Feet in 1 lb.	Breaking Strain in Lbs.	Diameter in Decimals of Inch.	Diameter in Mm.	Number of Feet in 1 lb.	Breaking Strain in Lbs.
·022	0·559	755	137	·048	1·218	165	587
·024	0·610	690	160	·051	1·294	150	640
·026	0·660	575	182	·055	1·396	130	750
·028	0·710	485	223	·059	1·50	110	850
·030	0·760	420	250	·063	1·60	95	970
·032	0·812	375	280	·067	1·70	85	1,000
·034	0·863	330	310	·071	1·80	75	1,240
·036	0·914	295	351	·074	1·89	68	1,340
·038	0·965	265	382	·078	1·98	61	1,430
·040	1·016	235	420	·082	2·08	55	1,600
·042	1·066	215	465	·086	2·18	50	1,750
·044	1·117	200	510	·090	2·29	40	1,900
·046	1·168	180	550	·098	2·49	38	2,280

PIANO WIRE

Music-wire Gauge.	Diameter.	Ultimate Tensile Strength.	Music-wire Gauge.	Diameter.	Ultimate Tensile Strength.
	In.	Lbs.		In.	Lbs.
12	·029	225	18	·041	395
13	·031	250	19	·043	425
14	·033	285	20	·045	500
15	·035	305	21	·047	540
16	·037	340	22	·052	650
17	·039	360			

HEMP CORD

Ultimate Tensile Strength.	Diameter.	Weight. Grammes per Metre.	Ultimate Tensile Strength.	Diameter.	Weight. Grammes per Metre.
Kg.	Mm.		Kg.	Mm.	
50	2·4	5	150	3·9	14
75	3·0	7	175	4·3	16
100	3·3	9	200	4·6	18
125	3·6	12			

STEEL TUBES

S.W.G. =	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
External Diameter.	Weight per Foot-Run, in Lbs.														
In. 3/8	0·337	0·320	0·300	0·277	0·251	0·234	·210	·194	·160	·145	·130	·120	·105	·090	·080
1/2	0·508	0·475	0·439	0·400	0·358	0·330	·296	·268	·232	·198	·175	·162	·142	·122	·110
5/8	0·679	0·630	0·578	0·523	0·465	0·426	·382	·342	·296	·251	·224	·204	·179	·154	·140
3/4	0·850	0·765	0·717	0·646	0·572	0·522	·468	·416	·360	·304	·273	·246	·216	·186	·170
7/8	1·020	0·940	0·856	0·769	0·679	0·618	·554	·490	·424	·357	·322	·288	·253	·218	·200
1	1·190	1·095	0·995	0·892	0·786	0·714	·640	·564	·488	·410	·371	·330	·290	·250	·230
1 1/8	1·363	1·250	1·134	1·015	0·893	0·810	·726	·638	·552	·463	·420	·372	·327	·282	·260
1 1/4	1·534	1·400	1·273	1·138	1·000	0·906	·812	·712	·616	·516	·469	·414	·364	·314	·290
1 3/8	1·705	1·560	1·412	1·260	1·107	1·000	·898	·786	·680	·569	·518	·456	·401	·346	·320
1 1/2	1·876	1·715	1·550	1·384	1·214	1·098	·984	·860	·744	·622	·567	·498	·438	·378	·350

STRENGTH OF BOLTS

Diameter.	Maximum Stress.	Effective Strength of Bolt.
In.	Lbs. per Sq. In.	Lbs.
$\frac{1}{2}$	2,000	250
$\frac{5}{8}$	2,500	500
$\frac{3}{4}$	3,000	900
$\frac{7}{8}$	3,400	1,450
1	3,900	2,150

WEIGHT OF BAR IRON (Lbs. per Foot Run)

Size in inches - -	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
Weight of square bar	·211	·475	·845	1·320	1·901	2·588	3·380
,, round bar	·165	·373	·663	1·043	1·493	2·032	2·654

WEIGHT OF FLAT BAR IRON (Lbs. per Foot Run)

Width in In.	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	2
Thickness												
$\frac{1}{4}$ in.	·42	0·53	0·63	0·74	0·84	0·95	1·05	1·16	1·26	1·37	1·48	1·69
$\frac{5}{16}$,,	·53	0·66	0·79	0·93	1·05	1·18	1·32	1·45	1·58	1·71	1·85	2·11
$\frac{3}{8}$,,	·63	0·79	0·95	1·11	1·26	1·42	1·58	1·74	1·90	2·06	2·22	2·53
$\frac{7}{16}$,,	·74	0·93	1·11	1·30	1·48	1·66	1·85	2·03	2·22	2·40	2·59	2·96
$\frac{1}{2}$,,	·85	1·06	1·27	1·48	1·69	1·90	2·11	2·32	2·53	2·74	2·95	3·38

WEIGHT OF SHEET IRON (Lbs. per Square Foot)

Thickness in In.	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
Weight per sq. ft.	2·517	5·035	7·552	10·07	12·588	15·106	17·623	20·141

BAMBOOS

Approximate Sizes, Weights, and Prices

Length in Feet.	Diameter at Top in Inches.	Diameter at Butt in Inches.	Total Weight in Lbs.	Approximate Price.	
				s.	*d.*
6	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{8}$	0	3
$6\frac{1}{2}$	$\frac{3}{4}$	1	$\frac{1}{2}$	0	4
$6\frac{1}{2}$	1	$1\frac{1}{8}$	$\frac{1}{2}$	0	5
$6\frac{1}{2}$	$1\frac{1}{8}$	$1\frac{3}{8}$	$\frac{1}{2}$	0	6
8	$\frac{3}{4}$	$\frac{7}{8}$ to $1\frac{1}{8}$	$\frac{3}{4}$	0	5
10	$\frac{3}{4}$	1 to $1\frac{1}{8}$	1	0	6
12	$\frac{3}{4}$	$1\frac{1}{8}$ to $1\frac{1}{4}$	2	0	8
14	$\frac{3}{4}$ to 1	$1\frac{1}{4}$ to $1\frac{1}{2}$	3	1	6
17	$\frac{3}{4}$ to 1	$1\frac{1}{4}$ to $1\frac{1}{2}$	$3\frac{1}{2}$	2	3
18	1	$1\frac{1}{2}$	4	3	0
18	$1\frac{1}{4}$	$1\frac{3}{4}$	6	4	0
18	$1\frac{1}{2}$	2	7	6	0
18	2	$2\frac{1}{2}$	9	8	0
18	$2\frac{1}{4}$	3	13	13	6
18	$2\frac{3}{4}$	$3\frac{1}{2}$	16	21	0
24	$1\frac{3}{4}$	$2\frac{1}{2}$	16	10	6
24	$2\frac{3}{8}$	3	18	16	0
24	$2\frac{1}{2}$	$3\frac{1}{2}$	20	25	0

CALCULATIONS OF STRENGTH OF STRUCTURAL PARTS

Definitions of Terms Used

Load.—The external forces acting on a structural member.

Live Load.—A load which does not remain constant, but varies continually.

Stress.—The internal forces in a member resisting the action of a load : numerically equal to the load per unit of area.

Strain.—The change of form produced by the action of a load, measured as the ratio of the deformation to the original size of the member. Thus for a tensile load, the *strain* is equal to the increase in length divided by the original length. *Hooke's law* states that the stress is proportional to the strain until the limit of elasticity is reached.

Elastic Limit.—The load at which a material subjected to its action no longer recovers its original shape on the load being removed.

Modulus of Elasticity.—Since the stress is proportional to the strain, the ratio $\frac{\text{stress}}{\text{strain}}$ for any material for a particular kind of stress is constant, and is known as the Modulus of Elasticity. The constant for tensile stress is known as Young's Modulus, and is denoted by E; for shearing stress, as the modulus of transverse elasticity, or C; for bulk compression, as the modulus of bulk compressibility, or K.

Bending Moment.—The bending moment at any section of a beam is the algebraic sum of all the external forces acting on the beam on either side of the section, multiplied by their respective distances from the section.

Moment of Resistance.—The moment of resistance of a beam at any section is the combination of internal forces brought into play to resist the bending moment, and is numerically equal to the strength modulus Z multiplied by the greatest fibre stress at the section.

The following symbols will be employed :—

F_t = total tensile load.
F^c = total compressive load.
F = total shearing load.
a = area.
M = bending moment.
I = moment of inertia.
Z = modulus of section.
y = distance of extreme fibre from neutral axis.
E = Young's modulus of elasticity.
n = factor of safety.
l = length in inches.
k = least radius of gyration.
g = acceleration of gravity.
f_t = tensile stress.
f_c = crushing stress.
f_s = shearing stress.

Tensile Load.—

$$F_t = af_t.$$

Compressive Load.—*Very short struts*—

$$F_c = a f_c.$$

Euler's formula for long struts—

Fixed at one end, free at other—

$$n.F_c = \frac{\pi^2 EI}{4l^2}.$$

Free at one end, guided at other—

$$n.F_c = \frac{\pi^2 EI}{l^2}.$$

Fixed at one end, guided at other—

$$nF_c = \frac{2\pi^2 EI}{l^2}.$$

Fixed at both ends—

$$nF_c = \frac{4\pi^2 EI}{l^2}.$$

Rankine-Gordon formula for struts—

$$nF_c = \frac{f_c a}{1 + c\frac{l^2}{k^2}}$$

Where $f_c = 16$ for wrought iron, and 3·2 for timber,
$c = \cdot 000028$ for wrought iron, and ·00033 for timber.

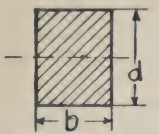
The above is for a strut fixed at both ends: c must be multiplied by 4 for a strut free at one end and guided at the other, or by 1·78 for a strut fixed at one end and hinged at the other.

Strut under a lateral bending moment:—

$$\frac{Wl}{4f_c Z} = \left(1 - \frac{w}{f_c}\right)\left(1 - \frac{w}{\beta}\right),$$

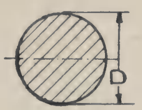
Where W is the total lateral load, uniformly distributed,
l ,, length in inches,
f_c ,, maximum compressive stress,
Z ,, modulus of section,
w ,, breaking load of strut per unit area.

$$\beta = \frac{\pi^2 EI}{4l^2.a}, \text{ as above.}$$



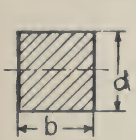
$$I = \frac{b^4}{12}$$

$$Z = \frac{1}{6}b^3$$



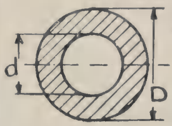
$$I = \frac{\pi}{64}D^4$$

$$Z = \frac{\pi}{32}D^3$$



$$I = \frac{bd^3}{12}$$

$$Z = \frac{1}{6}bd^2$$

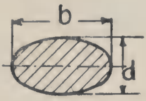


$$I = \frac{\pi}{64}(D^4 - d^4)$$

$$Z = \frac{\pi}{32}\,\frac{D^4 - d^4}{D}$$

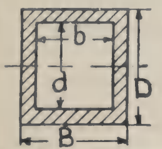
$$I = \frac{b^4}{12}$$

$$Z = \frac{\sqrt{2}b^3}{12}$$



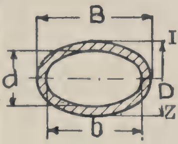
$$I = \frac{\pi}{64}bd^3$$

$$Z = \frac{\pi}{32}bd^2$$



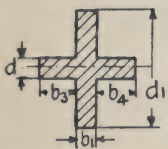
$$I = \frac{BD^3 - bd^3}{12}$$

$$Z = \frac{BD^3 - bd^3}{6D}$$



$$I = \frac{\pi}{64}(BD^3 - bd^3)$$

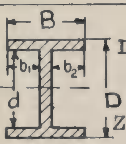
$$Z = \frac{\pi}{32}\left(\frac{BD^3 - bd^3}{D}\right)$$



b2 = b3 + b4

$$I = \frac{b_1d_1^3 + b_2d_2^3}{12}$$

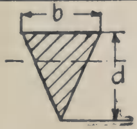
$$Z = \frac{b_1d_1^3 + b_2d_2^3}{6d_1}$$



b = b1 + b2

$$I = \frac{1}{12}(BD^3 - bd^3)$$

$$Z = \frac{1}{6}\left[\frac{BD_3 - bd^3}{D}\right]$$



$$I = \frac{bh^3}{36}$$

$$Z = \frac{bh^2}{24}$$

Moments of Inertia of different Sections

About Axis in Plane of Paper.

FIG. 2.

Loading and Stiffness of Beams

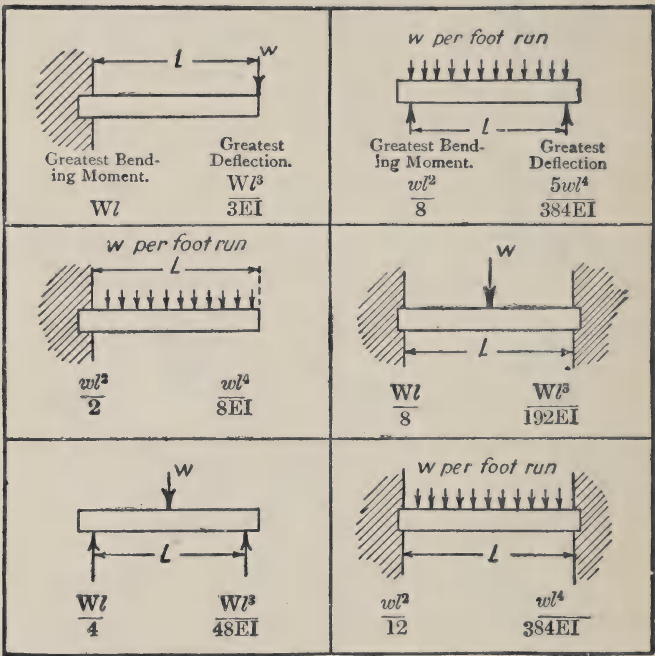


Fig. 23.

Springs

Plate Springs.

$$W = n.\ \frac{2bt^2}{l}f.$$

$$\delta = n\frac{Wl^3}{2Ebt^3}.$$

Spiral Springs.—

$$W = \frac{\pi d^3}{8D}f.$$

$$\delta = \frac{8Wl_1D^3}{\pi Cd^4}.$$

Where W = total load,
b = breadth of plates,
t = thickness of plate,
n = number of plates,
l = length between buckles,
l_1 = length of wire in spring,
f = maximum fibre stress,
δ = deflection under load W,
d = diameter of wire,
D = diameter of coil.

The lightest form of spiral spring is that made of thin circular tube, which has almost twice the resilience of a solid wire spring of the same weight. Moreover, the resilience of any given material is greater in spiral spring form than in any other form, for the same weight.

Shafts

$$T = \frac{\pi}{16} d^3 f \text{ (solid shaft).}$$

$$T = \frac{\pi}{16} \frac{d^4 - d_1^4}{d} f \text{ (hollow shaft).}$$

Where T = torque applied to shaft,
d = external diameter of shaft,
d_1 = internal diameter of shaft,
f = extreme stress.

Flywheel

$$\text{Greatest stress} = \frac{wv^2}{144g} = \frac{w \cdot \pi^2 d^2 n^2}{144g} \text{ (lbs. per square inch).}$$

Where w = weight of 1 cub. ft. of material of which wheel is composed,
v = velocity of rim in feet per minute,
d = diameter of wheel,
n = revolutions per minute.

Ball Bearings

Crushing load $P = 82{,}400\ nd^2$,
n = number of balls,
d = diameter of each ball, in inches,

Diameter of ball in inches	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	...
Crushing load (lbs.)	1,288	2,900	5,150	8,050	11,600	20,600	Per ball
Working load (lbs.)	160	360	640	1,000	1,450	2,570	,,

Thin Cylinders, Pipes

Greatest stress is given by $f = \frac{pd}{2t}$.

Where p = internal pressure, lbs. per square inch,
d = diameter of pipe,
t = thickness of pipe.

Tempers of Carbon Steel

Colour of Polished Surface.	Temperature of Quenching, ° F.	Colour of Polished Surface.	Temperature of Quenching, ° F.
1. Light straw	430	6. Light purple	520
2. Straw	450	7. Dark purple	530
3. Dark straw	470	8. Bright blue	550
4. Light brown	490	9. Blue	560
5. Dark brown	510	10. Dark blue	600

1, 2, 3 are the tempers for metal-cutting tools; 3, 4, 5 for wood-cutting tools; 5, 6, 7 for saws, hatchets, chipping chisels, and percussion tools; 8, 9, 10 for springs.

Tautness Meter.—A useful instrument was described by Mr Mervyn O'Gorman in his recent paper, "Problems Relating to Air-craft." This is made by the Cambridge Scientific Instrument Company, and permits of measuring the tension of any tiewire without cutting it.

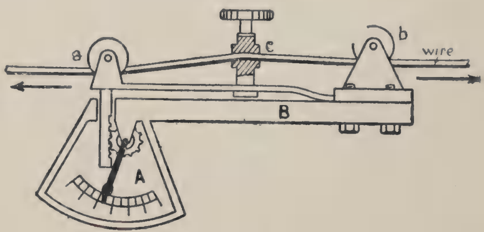


Fig. 24.

The principle of the appliance is that if a wire be stretched between two fixed points, a pull is required to deflect or bend it, and this pull is a measure of the stretching force. For this purpose the stretched wire rests on two rollers at *a* and *b* respectively, and is clamped gently at *c*.

The two rollers and the clamps are not a straight line, therefore the stiff spring to which they are attached is deflected, and the amount of this deflection is measured on a direct reading dial graduated in lbs.

DIVISION IV

ENGINES

All the engines used for the propulsion of aeroplanes are of the internal combustion class, and the fuel employed is in every case petrol. It is possible, however, that other fuels may come into use in the future.

The engines are of the single-acting type, in which driving impulses are received on one side of the piston only. The cycle of operations in the cylinder is either the four-stroke, or Otto, cycle, or the two-stroke cycle; at present the greater number of engines work on the four-stroke system, in which there is one driving impulse on the piston in every four strokes, or two revolutions, as follows: During the first, or *induction*, stroke, the exhaust valve is closed, and the explosive mixture of air and petrol vapour is drawn into the cylinder through the open inlet valve by the suction of the descending piston; during the second, or *compression* stroke, both valves are closed, and the mixture is compressed by the ascending piston into the clearance space in the "combustion head"; at, or just before, the end of the compression stroke the mixture is fired by an electric spark, and the expanding gases drive the piston down during the third stroke, known as the *explosion*, *expansion*, or *power* stroke, both valves remaining closed; just before the end of the power stroke the exhaust valve opens, and remains open during the whole of the fourth, or *exhaust* stroke, while the ascending piston drives the burnt gases out of the cylinder. The cycle then recommences with another induction stroke.

In the two-stroke cycle there is first a power stroke, in which the piston is driven forward by the firing of the petrol vapour, while both valves are closed, and the next charge is being slightly compressed beneath the piston. At the end of the power stroke the exhaust port opens, and the burnt gases escape from the cylinder. About the same time the inlet valve opens, and the mixture enters, being cut off after the piston has travelled a short distance on its upward stroke. The exhaust port has previously closed, and the mixture is then compressed by the ascending piston and fired at the top of the stroke. This is the ordinary two-stroke cycle: there is the serious disadvantage of the mixing of the burnt gases and the incoming charge, with the consequence of a less vigorous explosion.

Improvements have been effected in the cycle, notably in the N.E.C. engine. In this engine the power stroke takes place as just described, but at the end the exhaust valve alone opens, and remains so during the greater portion of the upward stroke. Near the end of the upward stroke the inlet valve opens, and the mixture, which has been previously compressed by a Root's blower, is admitted, and then fired as usual.

In an engine working on the Otto cycle, and having only a single cylinder, the shaft receives one rotative impulse in every four strokes, or in two revolutions. In a two-cylinder engine the shaft receives an impulse in every revolution. In a four-cylinder engine the shaft receives two impulses per revolution, and so on, the arrangement of firing being arranged as far as possible so that the impulses are given at regular intervals of time. Four-stroke engines of less than four cylinders are usually fitted with flywheels to make the turning effect more even, and to help the engine over the compression strokes. As a two-stroke engine has twice the number of impulses as an engine working on the Otto cycle with the same number of cylinders, in this case a flywheel is not so necessary.

The greater the number of impulses given to the shaft per revolution the more uniform is the rotary motion, and if uniformity were the only thing to be considered, the greater the number of cylinders in the engine the better would be the results. But with each cylinder a certain unavoidable amount of complication is introduced; accordingly, other things being equal, no more cylinders should be introduced than are necessary to achieve the required degree of uniformity.

No attempt appears to have been made to ascertain the deviation from uniform motion which is permissible in the case of aerial propellers.

The most important matter in connection with an aeroplane engine is reliability, combined with comparatively light weight. There is already among manufacturers a tendency to strengthen up their engines at the cost of some extra weight, and this is undoubtedly a step in the right direction. Moreover, the question of fuel economy is becoming hourly of more importance, since for a long journey a heavier, but more economical engine often weighs considerably less than one of the extremely light and extremely wasteful engines still in use, if the weight of the oil and petrol required for each is taken into account.

Existing engines may be divided into three main classes:—

1. Those developed from car engines, including vertical, vee, and horizontally opposed arrangements of the cylinders.
2. The stationary radial or semi-radial type, in which all the connecting rods work on one or two crankpins.
3. The rotary radial type, in which there is usually one crankpin.

Typical examples of 1 are the Green, E.N.V., and Darracq engines respectively; of 2 the Isaacson and R.E.P. engines; and of 3 the Gnome engine.

Work or Energy

Foot-pound.—In Great Britain the unit of work or energy is the foot-pound, being the work done by a force of 1 lb. exerted through a distance of 1 ft.

Kilogramme-metre.—On the Continent the unit of work or energy is the kilogramme-metre, being the work done by a force of 1 kg. exerted through a distance of 1 m.

(1 foot-pound = 0·138 kilogramme-metre.)

Power

Horse-power.—In Great Britain the unit of power is the horse-power, which represents the performance of work at the rate of 33,000 ft.-lbs. per minute.

Cheval-vapeur.—On the Continent the unit of power is the cheval-vapeur or metric horse-power, which represents the performance of work at the rate of 4,500 kg.-m. per minute.

(1 horse-power = 1·014 cheval-vapeur.)

Indicated Horse-power. — The horse-power developed in the engine cylinders is proportional to the force exerted on the pistons during the working stroke, and to the distance travelled by the pistons in feet per minute.

The force exerted on each piston is the product of the average effective pressure of the gas per square inch and the area of the piston in square inches.

If d = the diameter of the cylinder in inches,
s = the stroke in feet,
n = the number of revolutions per minute,
p = the average effective pressure on the pistons in pounds per square inch,
N = the number of cylinders.

Then—

The force exerted on the pistons $= \cdot 7854 d^2 \times p$.

The distance travelled by the pistons in feet per minute $= 2sn$.

To get the I.H.P. we divide the product of these two quantities by 4, because in the Otto cycle the force acts on the pistons for

only one-fourth of the distance travelled, we multiply by N, the number of cylinders, and finally we divide by 33,000, the number of foot-pounds per minute for each horse-power.

We have then—

$$\text{I.H.P.} = \frac{\cdot 7854 d^2 p \times 2sn \times \text{N}}{4 \times 33{,}000}.$$

If we assume that a mean effective pressure p of 90 lbs. per square inch is obtained in the cylinders, and that the distance travelled by the pistons $2sn$ is 1,000 ft. per minute, the above expression becomes :—

$$\text{I.H.P.} = 0{\cdot}5d^2\text{N} \text{ approximately.}$$

Brake Horse-power.—The foregoing gives the I.H.P., that is, the power developed in the engine cylinders, but a certain amount of the power is dissipated in the friction of the pistons, valves, bearings, etc., and as a consequence the actual power available for driving the propeller is considerably less. It is usual to reckon the power that is lost at 20 per cent., a figure which the test of the Clement-Talbot engine given on p. 82 confirms. Accordingly the horse-power which can actually be utilised may be taken at about 80 per cent. of the I.H.P. This actual horse-power is termed the Brake Horse-power, written B.H.P., because it represents the power which is obtained on test when a brake is employed to absorb all the useful power of the engine.

Allowing that the B.H.P. is only 80 per cent. of the I.H.P., the formula for the B.H.P. is :—

$$\text{B.H.P.} = 0{\cdot}4d^2\text{N}.$$

This corresponds with the rating for B.H.P. adopted by the Royal Automobile Club, and forms a very convenient and simple formula to represent the power which the engine may be expected to give.

It will be understood, of course, that if the engine works on a two-stroke cycle the B.H.P. will be rather less than twice as great as is given by the above formula.

Speed and Horse-power.—In the foregoing formulæ the distance travelled by the pistons is to be assumed to be 1,000 ft. per minute, but for cases in which this does not hold good a correction is necessary. In calculating the power of petrol engines, the pressure obtainable in the cylinder is estimated to be independent of the speed. This would mean that the B.H.P. is simply proportional to the speed, and this in fact holds good within wide limits.

THE RATINGS OF ENGINES

(In accordance with R.A.C. rules)

Diameter of Cylinders.		Corresponding R.A.C. Ratings for 1, 2, 3, 4, or 6-Cyl. Engines.				
		6-Cyl.	4-Cyl.	3-Cyl.	2-Cyl.	1-Cyl.
Mm.	In.					
60	2·36	13·4	8·9	6·7	4·5	2·23
61	2·40	13·8	9·2	6·9	4·6	2·30
62	2·44	14·3	9·5	7·1	4·8	2·38
63	2·48	14·8	9·8	7·4	4·9	2·46
64	2·52	15·2	10·2	7·6	5·1	2·54
65	2·56	15·7	10·4	7·8	5·2	2·61
66	2·60	16·2	10·8	8·1	5·4	2·70
67	2·64	16·7	11·1	8·3	5·6	2·78
68	2·68	17·2	11·5	8·6	5·7	2·87
69	2·72	17·7	11·8	8·8	5·9	2·95
70	2·76	18·2	12·1	9·1	6·1	3·04
71	2·80	18·7	12·5	9·4	6·2	3·12
72	2·84	19·3	12·8	9·6	6·4	3·21
73	2·87	19·8	13·2	9·9	6·6	3·30
74	2·91	20·3	13·6	10·2	6·8	3·39
75	2·95	20·9	13·96	10·5	6·98	3·49
76	2·99	21·5	14·3	10·7	7·2	3·58
77	3·03	22·0	14·7	11·0	7·3	3·67
78	3·07	22·6	15·1	11·3	7·5	3·77
79	3·11	23·2	15·5	11·6	7·7	3·87
80	3·15	23·8	15·9	11·9	7·9	3·97
81	3·19	24·4	16·3	12·2	8·1	4·07
82	3·23	25·0	16·7	12·5	8·3	4·17
83	3·27	25·6	17·1	12·8	8·5	4·27
84	3·31	26·2	17·5	13·1	8·7	4·37
85	3·35	26·9	17·9	13·4	8·96	4·48
86	3·39	27·5	18·3	13·7	9·2	4·58
87	3·43	28·1	18·8	14·1	9·4	4·69
88	3·46	28·8	19·2	14·4	9·6	4·80
89	3·50	29·5	19·6	14·7	9·8	4·91
90	3·54	30·1	20·1	15·1	10·0	5·02
91	3·58	30·8	20·5	15·4	10·3	5·13
92	3·62	31·5	21·0	15·7	10·5	5·25
93	3·64	32·2	21·4	16·1	10·7	5·36
94	3·70	32·9	21·9	16·4	10·96	5·48
95	3·74	33·5	22·4	16·8	11·2	5·59
96	3·78	34·3	22·8	17·1	11·4	5·71
97	3·82	34·98	23·3	17·5	11·7	5·83
98	3·86	35·7	23·8	17·8	11·9	5·95

THE RATINGS OF ENGINES—*Continued*

Diameter of Cylinders.		Corresponding R.A.C. Ratings for 1, 2, 3, 4, or 6 Cyl. Engines.				
		6-Cyl.	4-Cyl.	3-Cyl.	2-Cyl.	1-Cyl.
Mm.	In.					
99	3·90	36·5	24·3	18·2	12·2	6·08
100	3·94	37·2	24·8	18·6	12·4	6·20
101	3·98	37·9	25·3	18·96	12·6	6·32
102	4·02	38·7	25·8	19·3	12·9	6·45
103	4·06	39·8	26·3	19·7	13·2	6·58
104	4·10	40·2	26·8	20·1	13·4	6·70
105	4·13	40·98	27·3	20·5	13·7	6·83
106	4·17	41·8	27·8	20·9	13·9	6·96
107	4·21	42·6	28·4	21·3	14·2	7·10
108	4·25	43·4	28·9	21·7	14·5	7·23
109	4·29	44·2	29·4	22·1	14·7	7·36
110	4·33	45·0	30·0	22·5	15·0	7·50
111	4·37	45·8	30·5	22·9	15·3	7·63
112	4·41	46·7	31·1	23·3	15·6	7·78
113	4·45	47·5	31·7	23·8	15·8	7·92
114	4·49	48·4	32·2	24·2	16·1	8·06
115	4·53	49·2	32·8	24·6	16·4	8·20
116	4·57	50·0	33·4	25·0	16·7	8·34
117	4·61	50·9	33·96	25·5	16·98	8·49
118	4·65	51·8	34·5	25·9	17·3	8·63
119	4·69	52·7	35·1	26·3	17·6	8·78
120	4·73	53·6	35·7	26·8	17·9	8·93
121	4·76	54·5	36·3	27·2	18·2	9·08
122	4·80	55·4	36·9	27·7	18·5	9·23
123	4·84	56·3	37·5	28·1	18·8	9·38
124	4·88	57·2	38·1	28·6	19·1	9·53
125	4·92	58·1	38·8	29·1	19·4	9·69
126	4·96	59·0	39·4	29·5	19·7	9·84
127	5·00	59·99	39·99	29·99	19·99	9·99
128	5·04	60·96	40·6	30·5	20·3	10·16
129	5·08	61·9	41·3	30·96	20·6	10·32
130	5·12	62·8	41·9	31·4	20·9	10·47
131	5·16	63·8	42·6	31·9	21·3	10·64
132	5·20	64·8	43·2	32·4	21·6	10·80
133	5·24	65·8	43·9	32·9	21·9	10·97
134	5·28	66·8	44·5	33·4	22·3	11·13
135	5·32	67·8	45·2	33·9	22·6	11·30
136	5·36	68·8	45·9	34·4	22·9	11·47
137	5·39	69·8	46·6	34·9	23·3	11·64
138	5·43	70·9	47·2	35·4	23·6	11·81

THE RATING OF ENGINES—*Continued*

Diameter of Cylinders.		Corresponding R.A.C. Ratings for 1, 2, 3, 4, or 6 Cyl. Engines.				
Mm.	In.	6-Cyl.	4-Cyl.	3-Cyl.	2-Cyl.	1-Cyl.
139	5·47	71·9	47·9	35·9	23·96	11·98
140	5·51	72·9	48·6	36·4	24·3	12·15
141	5·55	73·9	49·3	36·96	24·6	12·32
142	5·59	75·0	50·0	37·5	25·0	12·50
143	5·63	76·1	50·7	38·0	25·4	12·68
144	5·67	77·1	51·4	38·5	25·7	12·85
145	5·71	78·2	52·1	39·1	26·1	13·03
146	5·75	79·3	52·8	39·6	26·4	13·21
147	5·79	80·4	53·6	40·2	26·8	13·40
148	5·83	81·5	54·3	40·7	27·2	13·58
149	5·87	82·6	55·0	41·3	27·5	13·76
150	5·91	83·7	55·8	41·8	27·9	13·95
155	6·10	89·3	59·6	44·7	29·8	14·89
160	6·30	95·2	63·5	47 6	31·7	15·87
165	6·50	101·3	67·5	50·6	33·8	16·88

Petrol

Petrol is obtained by the process of distillation from crude petroleum. The latter is of a highly complex character, containing many more or less volatile hydrocarbons, its exact composition varying according to the locality in which it is found. The derived product, petrol, which comes off in the earlier stages of distillation, is also of a complex character, and consists of a mixture of various members of the paraffin series, expressed by the general chemical formula, C_nH_{2n+2}, where n is any integer.

Commercial petrol has a specific gravity of 0·68 to 0·72, and consists mostly of Hexane (C_6H_{14}) and Heptane (C_7H_{16}). The lighter spirit known as gasoline has a specific gravity of about 0·64, and consists almost wholly of Pentane, C_5H_{12}. The lower the specific gravity of the petrol the higher is the amount of energy per lb., since the proportion of hydrogen to carbon is higher in the earlier members of the paraffin series, as can be seen readily from the formula given above.

Petrol is completely volatile in the air without the aid of artificial heat.

Calorific Value.—The calorific value of petrol is 19,000 to 21,000 B.Th.U. per lb., that is to say, the complete combustion of 1 lb. of the fuel will release from 19,000 to 21,000 British thermal units of heat.

A *B.Th.U.*, or British thermal unit, is the amount of heat required to raise 1 lb. of water 1° F. in temperature at or near 31·9° F., the temperature at which the density of water is a maximum.

If the nature or source of the fuel is known, the calorific value can always be estimated within 5 per cent. without knowing the exact composition of the fuel (G. H. Baillie).

Quality.—Good petrol should fulfil the following requirements :—

1. It should enable the engine to start easily from cold.
2. It should not smell too badly before or after combustion.
3. Its specific gravity and calorific value should be within the limits stated.
4. It should not lead to deposits in the cylinders or on the valves under any of the various conditions of running.

Petrol Consumption

The commercial efficiency of petrol engines is expressed in terms of the consumption of petrol per horse-power per hour.

As regards the working mixture of petrol and air, the proportions which give the greatest power for a given size of engine are not the proportions which give the lowest consumption of petrol per horse-power.

Generally it is usual in stationary engines to work at high economy rather than at high power, but in aeroplane engines the reverse holds good, it being of more importance to secure large power for a given weight than low fuel consumption.

Accordingly, no particular mixture can be described as the best for petrol engines under all circumstances. In the test of the Clement-Talbot engine (p. 82), for example, the highest power was obtained with a mixture by weight of 1 of petrol to 11·6 of air, while the highest economy, that is the lowest consumption per B.H.P., was obtained with 1 of petrol to 16·9 of air. As the economy rises the power falls, but in practice it is usual to employ mixtures of 1 to 10 or 12 to get maximum power.

For this particular engine the consumption of petrol per B.H.P. per hour varies, as will be seen from the test, between 0·614 and 0·75 lb. according as the engine is working at the highest economy or the highest power.

At the recent Military Aeroplane Trials (August 1912), the 65 H.P. Green engine took as little as 4 gals. of petrol per hour, *i.e.*, half a gallon per horse-power hour (15 miles to the gallon). The 120 H.P. Austro-Daimler engine had a consumption of 9 gals. per hour, or 0·6 gal. per horse-power hour (8 miles to the gallon). The 70 H.P. Renault consumed 7 gals. per hour, or 0·78 gal. per horse-power hour (7·9 miles to the gallon). The 100 H.P. (80 B.H.P.) Gnome engine used 8·7 gals. per mile, or 0·87 gal. per horse-power

hour (9·6 miles per gallon). Of course an aeroplane virtually flies up a grade of one in six all the time, hence the above results are excellent, especially when the high speed of travel is borne in mind.

The cost of petrol in pence per mile for the Avro biplane, with Green engine, was about $1\frac{1}{4}$d., and the cost of lubricating oil was just under a $\frac{1}{2}$d., petrol being taken at 1s. 6d. per gallon, and oil at 4s. 6d. per gallon. The Cody biplane with Austro-Daimler engine took $2\frac{1}{4}$d. worth of petrol and $\frac{1}{3}$d. worth of oil. The petrol consumption of the Maurice Farman biplane with Renault engine was just under $2\frac{1}{2}$d. per mile, and the oil consumption nearly $\frac{3}{4}$d. While the corresponding cost of the Hanriot monoplane, with 100 H.P. Gnome engine, was nearly 2d. for petrol and nearly $1\frac{3}{4}$d. for oil.

Thermal Efficiency

Taking the calorific value of petrol at 19,000 B.Th.U. per lb., since the mechanical work which can be performed by the dissipation of 1 B.Th.U. is 778 ft.-lbs., it follows that if all the heat could be utilised the combustion of 1 lb. of petrol would result in the performance of $19{,}000 \times 778 = 14{,}782{,}000$ ft.-lbs. of work.

According to the above, the petrol consumed in the engine per hour for each B.H.P. taken at ·75 lb. represents 11,086,500 ft-lbs. of work. As a horse-power represents $33{,}000 \times 60 = 1{,}980{,}000$ ft.-lbs. per hour, the heat in ·75 lb. of petrol represents 5·6 H.P. exerted for one hour. Since the quality of fuel used represents 5·6 H.P. hours, and we only get 1 B.H.P. hour for it, the ratio of the heat utilised is to the total heat in the fuel 1 : 5·6, approximately 18 : 100. The thermal efficiency of the engine is therefore about 18 per cent.

TEST OF A CLEMENT-TALBOT FOUR-CYLINDER MOTOR CAR ENGINE

Cylinder Diameter 3·34 in., Stroke 4·73 in. (85 by 120 mm.)
(Professor Watson)

Mixture.	Mean Effective Pressure on Pistons per Sq. In.	I.H.P.	B.H.P.	Revolutions per Minute.	Petrol per I.H.P. per Hour.	Petrol per B.H.P. per Hour.	Thermal Efficiency.
					Lb.	Lb.	
1 to 11·6	90·0	24·2	19·9	1,284	0·614	0·750	0·222
1 to 16·9	78·6	20·1	16·2	1,219	0·495	0·614	0·275

LIBRARY
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PARTICULARS OF VARIOUS AEROPLANE ENGINES

Name of Engine.	Type.	Horse-power.	Weight.	Revolutions per Minute.	Cylinders. No	Bore	Stroke	Cooling.	Bearings.	Lubrications.	Ignition.	Carburettor.	Firing Interval.	Petroleum Consumption.	Name of Maker.	Remarks.
A.B.C. -	4-cycle vertical	40	Lbs. 185*	1,300	4	4¾ in. 120·7 mm.	4¾ in. 120·7 mm.	Water	Five	Forced by geared pump	Bosh H.T. single or dual	...	Degs. 180	Pints per H.P./Hr. ·6	Sir W. G. Armstrong, Whitworth & Co., Ltd., Great George Street, London, S.W.	*Weight does not include flywheel, weight 20 lbs. Separate steel cylinders, with corrugated copper water jackets. Mechanically operates valves.
A.B.C. -	4-cycle vee, 90°	80	275†	1,250	8	4¾ in. 120·7 mm.	4¾ in. 120·7 mm.	Water	Five	Forced by geared pump	Bosh H.T. single or dual	...	90	·65		As above. †Weight of flywheel, 18 lbs., not included.
A.B.C. -	4-cycle vee, 90°	120	400‡	1,250	12	4¾ in. 120·7 mm.	4¾ in. 120·7 mm.	Water	Five	Forced by geared pump	Bosh H.T. single or dual	...	60	·65		As above. ‡Weight of flywheel, 16 lbs. extra.
Adams-Farwell	4-cycle rotary	72	380	1,000	5	6 in.	6 in.	Air	...	Forced	Dual	None	144	·8	Adams-Farwell Co., Dubuque, Iowa, U.S.A.	Combined inlet and exhaust valves. Auxiliary exhaust ports.
Anzani -	4-cycle radial Y	25	118	1,250	3	Mm. 105	Mm. 105	Air	Ball	Forced	Gibaud (or V.H.)	Zenith	240	g.p.h. 2·5	The British Anzani Engine Co., Ltd., 30 Regent Street, London, W. Works—Coventry	Angle between cylinders 120°; Oil consumption g.p.h. 0·5
Anzani -	4-cycle radial Y	30	121	1,250	3	105	120	Air	Ball	Forced	Gibaud (or V.H.)	Zenith	240	2·6		120°; 0·5
Anzani -	4-cycle radial double star	40/45	154	1,250	6	90	120	Air	Ball	Forced	Gibaud (or V.H.)	Zenith	120	3		60°; 0·75
Anzani -	4-cycle radial double star	50/55	200	1,250	6	105	120	Air	Ball	Forced	Gibaud (or V.H.)	Zenith	120	4·5		60°; 1
Anzani -	4-cycle radial double star	60/65	242	1,250	10	90	120	Air	Ball	Forced	Gibaud (or V.H.)	Zenith	72	5		36°; 1·25
Anzani -	4-cycle radial double star	70/80	238	1,250	10	90	130	Air	Ball	Forced	Gibaud (or V.H.)	Zenith	72	5·6		..; 1·3
Anzani -	4-cycle radial double star	80/90	330	1,250	10	105	125	Air	Ball	Forced	Gibaud (or V.H.)	Zenith	72	6·5		..; 1·5
Anzani -	4 cycle radial double star	100	363	1,250	10	105	145	Air	Ball	Forced	Gibaud (or V.H.)	Zenith	72	7		..; 2
Anzani -	4-cycle radial double star	125	464	1,250	10	115	155	Air	Ball	Forced	Gibaud (or V.H.)	Zenith	72	9·5		..; 2
Anzani -	4-cycle radial quadruple star	200	682	1,250	20	105	140	Air	Ball	Forced	Gibaud (or V.H.)	Zenith	...	14·5		18°; 3
Canton-Unné	4-cycle stationary radial	130	600	1,250	9	122	140	Water	... ...	Forced	H.T. magneto	Zenith	..	·7	Dudbridge Iron Works, Ltd., 87 Victoria St., S.W.	Cylinders of steel, with copper water jackets. Mechanically operated valves.
Clément-Baynard	4-cycle vertical	40	242	1,500	4	100	120	Water (pump)	... ...	Splash	Clement	Automatic	180	·75	Clément-Bayard, Ltd., Quai Michelet Levallois Perret, France	Cylinders cast *en bloc* with copper jackets. Mechanically operated valves.
Darracq -	4-cycle horizontal opposed	25-30 50-60	121 242	1,300 1,200	2 4	130 130	120 120	Water Water	... ...	Forced	H.T. magneto	...	360 360	·75	Darracq & Co., Suresnes, Seine, France	.. ..
Darracq -	4-cycle vertical	50-60 100-120	385 550	1,200 1,000	4 4	120 170	140 140	Water Water	... ...	Forced Forced	H.T. magneto	...	180 180	·75	As above	.. ..
E.N.V. -	4-cycle vee, 90°	35	166	1,260	8	85	90	Water	Six main ball bearings. Ball thrust bearings to crankshaft.	Forced to all bearings	H.T. magneto	Zenith	90	·6	E.N.V. Motor Synd., Hythe Rd., Willesden	Separate cylinders of C.I., electrolytically deposited copper jackets. Mechanically operated valves. Price £350.
E.N.V. -	4-cycle vee, 90°	60	310	1,120	8	105	110	Water	As above	Forced to all bearings	Magneto	White & Poppe	90	·6	As above	Mechanically operated valves. Cylinders as above. Price £450. On a test by Mr M. O'Gorman, this engine showed an oil consumption of ·1718 pint per horse-power per hour, petrol ·57 pint per horse-power per hour, and developed 64 B.H.P. for a weight of 337 lbs.
E.N.V. -	4-cycle vee, 90°	100	525	1,000	8	130	150	Water	As above	Forced to all bearings	Dual magneto and coil	White & Poppe	90	·8	As above	Cylinders of steel. Mechanically operated valves.
Fitz -	4-cycle rotary	60	200	1,000	6	130	110	Air	... ...		Mea magneto	Filtz	...	·8	...	C.I. gilled cylinders.
Gnome -	4-cycle rotary	50	167	1,200	7	110	120	Air	Ball	Oil circulation by pump	Magneto	Forced feed	102·8	·8	British Agents, The Gnome Engine Co., 47 Victoria St., Westminster	Cylinders of forged steel. Inlet valves in piston heads, automatic. Price £520.
Gnome -	4-cycle rotary	70	184	1,200	7	130	120	Air	Ball	As above	Magneto	Forced feed	102.8	·78	As above	As above. Price £640.
Gnome -	4-cycle rotary	100	220	1,200	14	110	120	Air	Ball	As above	Magneto	Forced feed	51.4	·87	As above	As above. Price £960.
Green -	4-cycle vertical	30	193	1,100	4	105	120	Water	White metal	Forced to crankshaft Valve mechanism in oil bath	Magneto, single or dual	Green non-float	180	·575	Green Engine Co., Ltd., 166 Piccadilly, London, W.	Cylinders, steel copper jackets detachable. Overhead mechanically operated valves.
Green -	4-cycle vertical	50	310	1,050	4	140	146	Water	White metal	As above	As above	Green non-float	180	·5	As above	As above. Supplementary exhaust ports can be fitted.
Grégoire-Gyp	4-cycle vertical	24	128	1,600	4	80	132	Water, thermo-syphon	Three main ball bearings	Forced	Magneto	Float feed	...	·8	Grégoire-Gyp Co., Rue de Saint Cloud, Suresnes, France	C.I. cylinders cast *en bloc*. Overhead mechanically operated valves.
Grégoire-Gyp	4-cycle vertical	35	172	1,600	4	92	140	Water, thermo-syphon	Three main ball bearings	Forced	Magneto	Float feed	...	·8	As above	As above.
Grégoire-Gyp	4-cycle vertical	50	242	1,400	4	100	160	Water, thermo-syphon	Three main ball bearings	Forced	Magneto	Float feed	...	·8	As above	As above.
Isaacson -	Stationary radial, 4-cycle	50	195	800	7	90	115	Air	Ball	Forced	Bosch magneto	White & Poppe	102.8	·48	Isaacson Radial Engine Co., Ltd., Boyne Works, Leeds	Cylinders C.I., gilled. The propeller is mounted concentrically with the crankshaft, and is driven by a two-to-one induction gear. Overhead mechanically operated valves. Oil consumption, 1·1 pints per hour.
Isaacson -	4-cycle stationary radial	100	290	800	14	90	115	Air	Ball	Forced	Bosch magneto	White & Poppe	51·4	·48	Isaacson Engine Co., Boyne Works, Leeds	As above. Oil consumption, 2·7 pints per hour.
Lamplough	2-cycle rotary	102	300	1,000	6	4 in.	2½ in.	Air	Ball throughout	Forced	Bosh dual	Own	30	·85	Lamplough & Son, Ltd., Willesden Junction	Mechanically operated exhaust valves in heads of cylinders. The motor includes a blower to feed the mixture to the cylinders. Cylinders of steel, gilled.
Oerlikon -	4-cycle horizontal opposed	50	165	1,300	4	100	160	Water	... ...	By gravity	H.T. magneto	Two	...	...	...	Steel Cylinders, with aluminium jackets. Mechanically operated valves.
Renault -	4-cycle vee, 90°	50	374	1,800	8	90 mm.	120 mm.	Air, by fan	White metal	Splash or forced	Bosch magneto	Renault	90	·78	Renault Frères, 15 Rue Gustave-Sandoz, Billancourt, Seine, France	Overhead mechanically operated valves. Propeller is attached to camshaft, turning at half engine speed. Price £440.
R.E.P. -	4-cycle semi-radial	40	350	1,200	5	130	160	Air	... ...	Forced to all bearings	Bosch magneto	R.E.P.	...	·8	Établissements R. Esnault Pelterie, rue de Silly, Billancourt, Seine, France	C.I. gilled cylinders. Overhead mechanically operated valves.
Salmson - (See Canton-Unné above)																
Viale -	4-cycle stationary radial	55	350	1,250	5	130	160	Air	.. ...	Forced	H.T. magneto	Own	...	·8	—	Gilled C.I. Cylinders.
Vickers	4-cycle	50	240	1,200	5	4 in.	5·5 in.	Air	.. ...	Forced	Bosch dual	Own	14	·7	Vickers, Ltd., Broadway, Westminster	Price £480.
R.E.P.	semi-radial	60	330	1,200	5	4·4 in.	6·4 in.	Air	... ...	...	...	...	...	...		Price £560.
Wolseley	4-cycle vee, 90°	60	300*	1,200	8	3¾ in.	5½ in.	Water	Three main bearings	Forced	Bosch dual	Wolseley annular float	90	·6	Wolseley Motors Ltd., Birmingham	Separate steel cylinders with C.I. heads and aluminium jackets. Steel pistons. Overhead valves, automatic inlet, mechanically operated exhaust. *Weight does not include flywheel.
Wolseley	4-cycle vee, 90°	120	580*	1,200	8	5 in.	7 in.	Water	Three main bearings	Forced	Bosch dual	Wolseley annular float	90	·62	As above	All valves mechanically operated, otherwise as above. *Weight does not include flywheel.

N.B.—For particulars of engines which took part in the 1914 War Office Trials see over page.

HEAT VALUES OF FUELS

			Calories.	B.Th.U.		H.P.
Petrol	1 kg.	=	11,000 =	43,500	per hour =	17·1
,,	1 pt.	=	4,500 =	17,800	,, =	7·0
,,	1 lb.	=	4,800 =	18,900	,, =	7·50
				Ft.-Lbs.		
,,	1 ,,	=		15,000,000	,, =	7·50
Benzol	1 ,,	=		14,000,000	,, =	7·00
Paraffin	1 ,,	=		18,000,000	,, =	9·00
Coal	1 ,,	=		12,000,000	,, =	6·00
Alcohol, 100 per cent.	1 ,,	=		9,800,000	,, =	5·00
Methylated, 83 ,,	1 ,,	=		8,600,000	,, =	4·30
Gas (coal)	1 cub. ft.	=		550,000	,, =	0·28

			B.Th.U.	
Hydrogen	1 lb.	=	53,340	burnt to steam.
Carbon	1 ,,	=	4,450	,, CO.
,,	1 ,,	=	10,170	,, from CO to CO_2.

Particulars of Various Aeroplane Engines.

In the foregoing table, the revolutions per minute are those at which the engine develops the stated horse-power. The petrol consumption, which is given in pints per horse-power per hour, is that given by the makers of the engine. The "firing interval" is the angle in degrees through which the crankshaft turns between any two successive explosions. In some cases—for example in a radial engine with an even number of cylinders — this is not constant, and so is not given.

DIVISION V

EXAMPLES OF ACTUAL MACHINES

BLACKBURN

Monoplane, Non-lifting Tail

Span - - - -	38 ft. 4 in.
Overall length - -	33 ft.
Area of main planes -	288 sq. ft.
,, fixed tail plane -	25 ,,
,, elevator - -	12 ,,
,, rudders - -	7½ ,,
Aspect ratio (mean) -	4·8
Weight - - - -	800 lbs.
Engine - - - -	50 H.P. Isaacson.
Control - - - -	Hand-wheel mounted on horizontal shaft: rotates for wing-warping, is raised or lowered for elevation, and moved sideways to operate the rudder.
Material - - - -	Ash.

The wings, which are double surfaced, are set at a dihedral angle of 1 in 12: the main spars are of I section, the rear spars being hinged to facilitate warping. A small skid is fitted at the extremity of each wing. The machine flies at about 55 miles an hour with a 10-ft. Blackburn propeller, 5 ft. 9 in. pitch, revolving at half-engine speed (*i.e.*, about 500 revs. per min.).

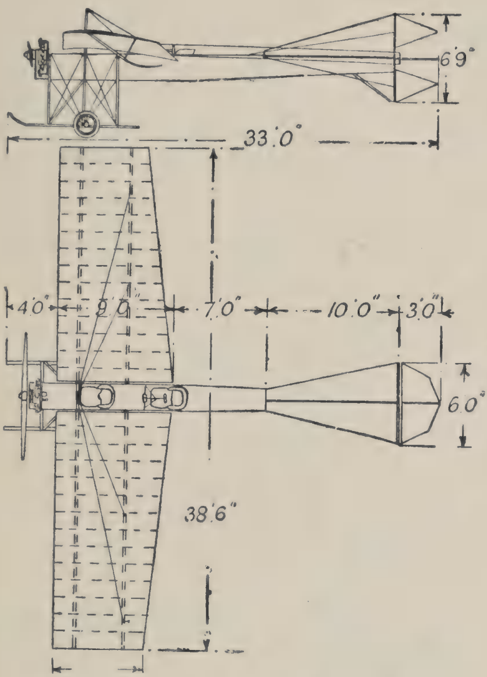


FIG. 25.—Blackburn Monoplane.

BLÉRIOT

Monoplane, Lifting Tail (single-seater)
,, Non-lifting Tail (two-seater)

	Single-seater.	Two-seater.
Span - - - - -	29 ft. 6 in.	36 ft.
Overall length - -	25 ,, 6 ,,	27 ft. 6 in.
Area of main planes -	187 sq. ft.	263 sq. ft.
,, fixed tail plane	...	86 ,,
,, elevators -	...	18 ,,
,, rudder -	...	11 ,,
Aspect ratio - - -	5·2	4·2

	Single-seater.	Two-seater.
Weight	550 lbs	700 lbs.
Engine	50 H.P. Gnome.	50 H.P. Gnome.
Control	Warping by sideways motion of lever, elevator by to-and-fro motion of lever, rudder by pivoted foot-rest.	
Material	Oregon pine, main spars of ash.	

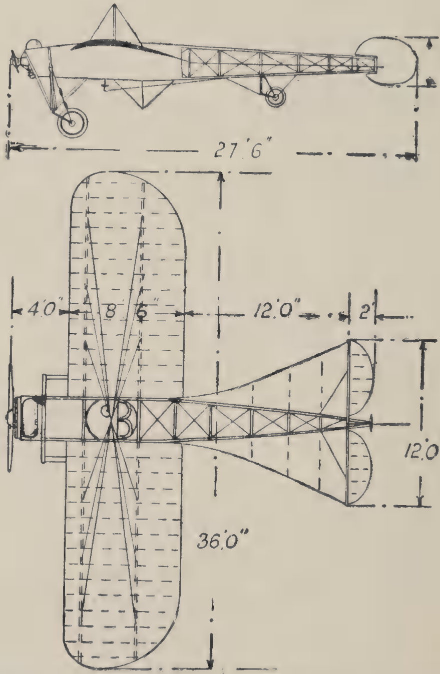


FIG. 26.—Blériot Monoplane (Two seater).

The wings are double surfaced.
The wheels of the landing chassis are mounted "castor" fashion.

BRÉGUET

Biplane, Tail carries Weight of Rear Framework

Span - - - - -	45 ft. 9 in.
Overall length - - -	28 ft.
Area of main planes - -	$327\frac{1}{2}$ sq. ft.
,, fixed tail plane -	21 ,,
,, elevator - -	$44\frac{1}{2}$,,
,, rudder - - -	20 ,,
Aspect ratio, upper plane	9·6
,, lower plane -	6
Weight, without pilot -	1,200 lbs.
Engine - - - -	R.E.P., Renault, Canton-Unné, as required.

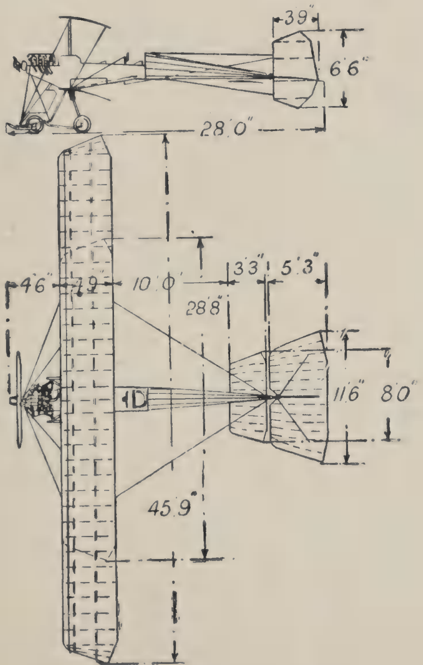


FIG. 27.—Bréguet Biplane

Control	Hand-wheel, rotates for steering, moved sideways for wing warping, moved to and fro for elevating.
Material	Steel.

There are four struts only between the upper and lower decks: each deck is carried by one main spar of tubular section, and the ribs are flexibly connected to this spar. The entering edges of the decks (which are double surfaced) are covered with sheet aluminium. The propeller runs at half-engine speed. The front wheel of the landing chassis is steerable and is interconnected with the rudder;

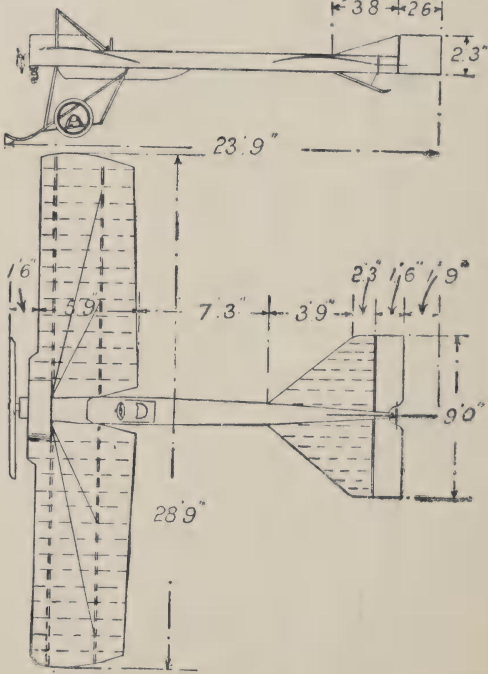


FIG. 28.—Deperdussin Monoplane.

the rudder and elevator are fixed together and connected to the fuselage by a universal joint. The wings fold back against the body for storage purposes.

DEPERDUSSIN

Monoplane, Lifting Tail

Span	28 ft. 9 in.
Overall length	24 ,, 9 ,,
Area of main plane	150 sq. ft.
,, fixed tail plane	28 ,,
,, elevator	12 ,,
,, rudder	5½ ,,
Aspect ratio	5
Weight	550 lbs.
Engine	50 H.P. Gnome.
Control	Hand-wheel, rotates for wing warping, moved to and fro for elevating. Rudder actuated by foot lever.
Material	Wood.

BRISTOL

Monoplane (no Fixed Tail)

Span	30 ft.
Overall length	24 ft. 6 in.
Area of main planes	166 sq. ft.
,, elevator	16 ,,
,, rudder	7 ,,
Aspect ratio	4·9
Weight	...
Engine	50 H.P. Gnome.
Control	Rudder actuated by pivoted foot-rest; hand lever moved sideways to warp wings to and fro to operate elevator.

The wings, which are single surfaced, are set at a slight dihedral angle; the camber and angle of incidence are small. The main spars are of steel, cored with wood. There is no fixed tail plane,

and the rear elevator is balanced by being hinged about a point near its centre.

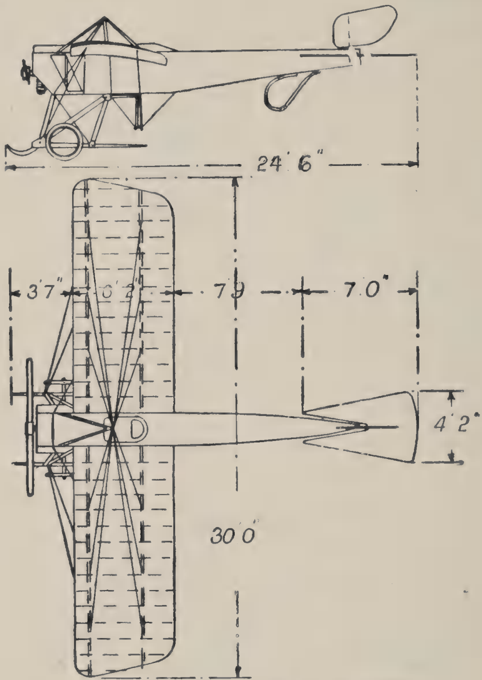


FIG. 29.—Bristol Monoplane.

BRISTOL

Biplane, Lifting Tail

	Military Type.	Ordinary Type.
Span - - -	46 ft. 6 in.	34 ft. 6 in.
Overall length - - -	38 ,, 6 ,,	38 ,, 6 ,,
Area of main planes - -	517 sq. ft.	457 sq. ft.
,, fixed tail planes -	89 ,,	...
,, rear elevator -	$22\frac{1}{2}$,,	...
,, leading elevator -	$30\frac{1}{2}$,,	...
,, rudders - -	26 ,,	...
Aspect ratio (upper plane)	7	...

	Military Type.	Ordinary Type
Aspect ratio (lower plane)	...	5·9
Weight - - -	900 lbs.	800 lbs.
Engine - -	50 H.P. Gnome.	
Control - - -	Vertical lever, moved sideways to work balancer, to and fro to actu ate elevator. Rudder worked by pivoted foot-rest.	
Material - - -	Ash and silver spruce.	

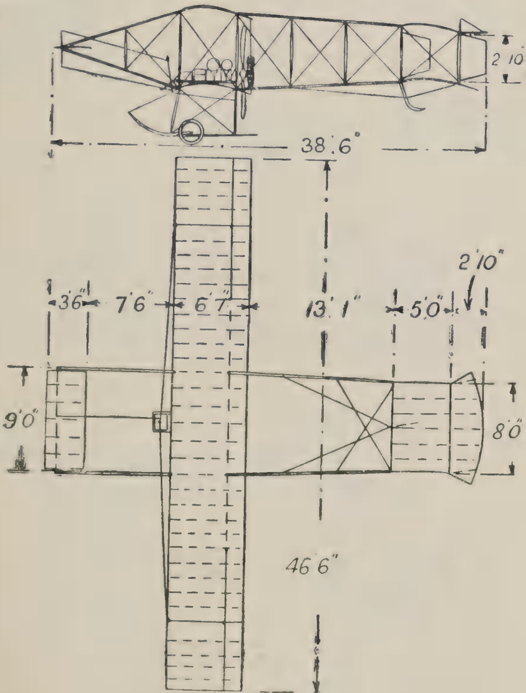


Fig. 30.—Bristol Biplane.

This machine is fitted with "fore and aft control," the leading and rear elevators being connected together. The main planes are divided in the centre for transport or storage, and the extensions, on the military type, can be dismounted or erected in a short time at will.

A tractor biplane is also made by this firm.

FLANDERS

Monoplane, Non-lifting Tail

Span	35 ft.
Overall length	31 ft. 9 in.
Area of main planes	200 sq. ft.
,, fixed tail plane	25 ,,
,, elevators	12·5 ,,
,, rudder	6 ,,
Aspect ratio	...
Weight	1,000 lbs.
Engine	60 H.P. Green.
Control	...
Material	...

The speed of this machine is about 60 miles per hour, with a propeller 7 ft. 10 in. diameter and 6 ft. pitch.

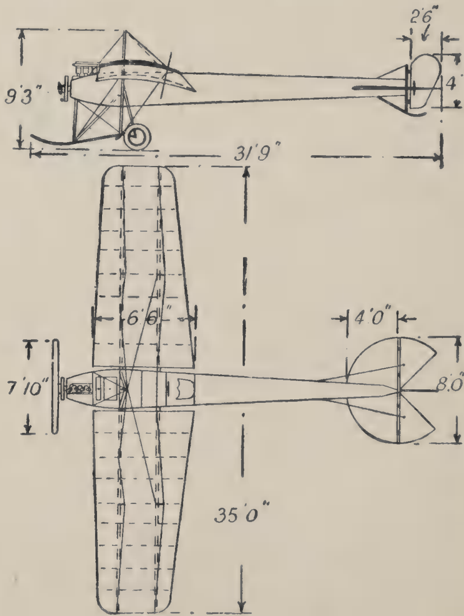


FIG. 31.—Flanders Monoplane

BOREL

Monoplane, Lifting Tail

Span	31 ft. 3 in.
Overall length	21 ,, 9 ,,
Area of main planes	160 sq. ft.
,, fixed tail plane	12 ,,
,, elevator	11 ,,
,, rudder	9 ,,
Aspect ratio	5·2
Weight, without pilot	440 lbs.
Engine	50 H.P. Gnome.
Control	Lever, moved sideways to warp wings, to and fro to work elevator. Rudder actuated by pivoted foot-rest.
Material	Ash.

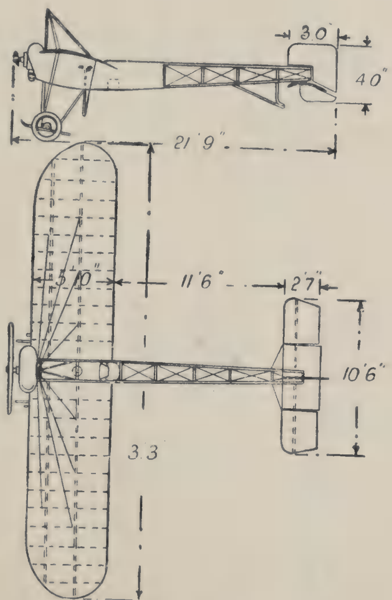


Fig. 32.—Borel Monoplane

ROE

Biplane, Non-lifting Tail

Span - - - -	31 ft.
Overall length -	26 ,,
Area of main planes -	310 sq. ft.
,, fixed tail plane	31 ,,
,, elevators -	14 ,,
,, rudder - -	11 ,,
Aspect ratio - -	6·2
Weight - - -	500 lbs.
Engine - - -	30 H.P. Green.
Controls - - -	Hand-wheel, moved to and fro to elevate, turned to warp wings. Rudder operated by two separate pedals.

This machine flies at 45 to 50 miles per hour with its Avro propeller of 8 ft. 4 in. diameter by 3 ft. 6 in. pitch, turning at 1,100 revs. per min.

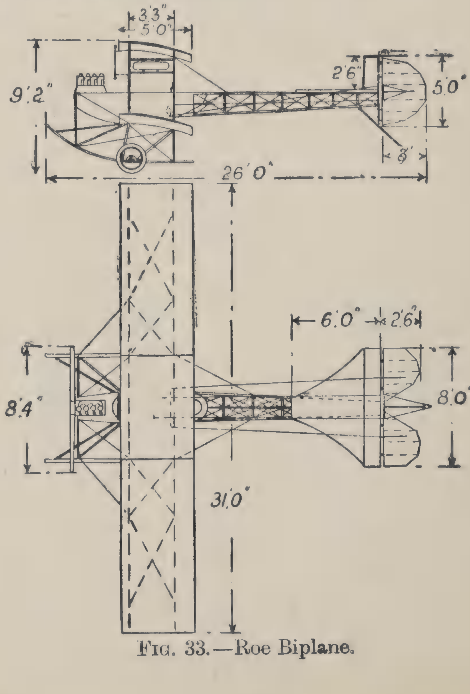


Fig. 33.—Roe Biplane.

ROE

Triplane, Non-lifting Tail

Span - -	32 ft.
Overall length - -	30 ,,
Area of main planes	294 sq. ft.
,, fixed tail plane -	38 ,,
,, elevators - -	13 ,,
,, rudder - -	6 ,,
Aspect ratio, upper planes	9·1
Aspect ratio, lowest plane	5·7
Weight - - - -	650 lbs.
Engine - -	35 H.P. Green.

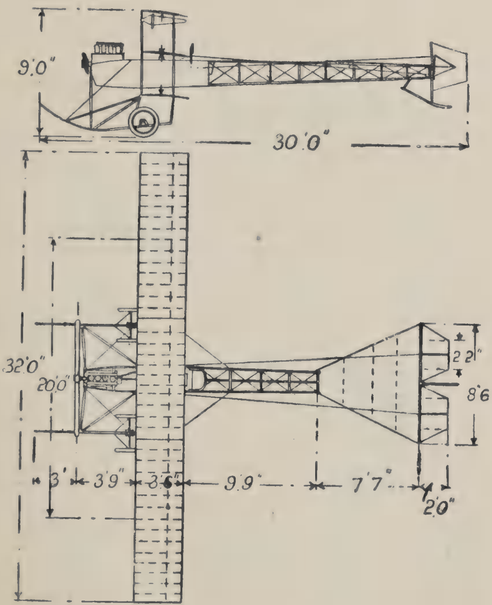


FIG. 34.—Roe Triplane

Control - - - -	Hand-wheel on steering column for wing-warping; elevator actuated by to-and-fro motion of steering column, rudder by pivoted foot-rest.
Material - - - - -	

NIEUPORT

Monoplane, Non-lifting Tail

	Two-seater Type.
Span - - - - -	36 ft.
Overall length - -	27 ft. 6 in.
Area of main planes -	220 sq. ft.

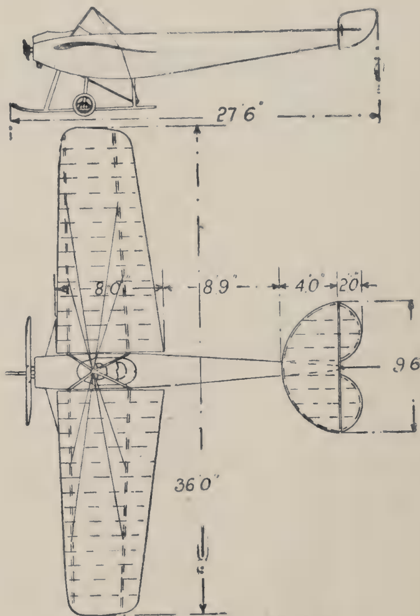


Fig. 35.—Nieuport Monoplane.

	Two-Seater Type.
Area of fixed tail plane	30 sq. ft.
,, elevator	13½ ,,
,, rudder	6 ,,
Aspect ratio (mean)	5·5
Weight	715 lbs.
Engine	50 H.P. Gnome.
Control	Wings warped by foot lever, elevator actuated by to-and-fro motion of hand lever, rudder by lateral motion of hand lever.

The wings, which are set at a slight dihedral angle, are double surfaced, and the camber decreases toward the trailing edges. The single-seater type of this machine has flown with an 18 H.P. Darracq engine.

SHORT

Biplane, Lifting Tail

	Standard Type.	Double-engined Type.
Span	46 ft.	34 ft.
,, lower plane	32 ,,	...
Overall length	40 ft. 6 in.	45 ft.
Area of main planes	517 sq. ft.	435 sq. ft.
,, fixed tail plane	65 ,,	65 ,,
,, rear elevator	26 ,,	29 ,,
,, front elevator	30 ,,	29 ,,
,, rudders	31 ,,	45 ,,
Aspect ratio	6·8	5
Weight	...	...
Engine	50 H.P. Gnome.	Two 50 H.P. Gnomes.
Control	Lever, moved sideways for balancing, to and fro for elevating. Rudder worked by pivoted foot-rest.	
Material	Silver spruce.	

The construction of both the above types of aeroplane is generally similar; the single-engined type has a single divided rudder. The front propellers in the double-engined type are driven from the engine by chains, the left-hand chain being crossed. The "standard" machine has an extended upper plane.

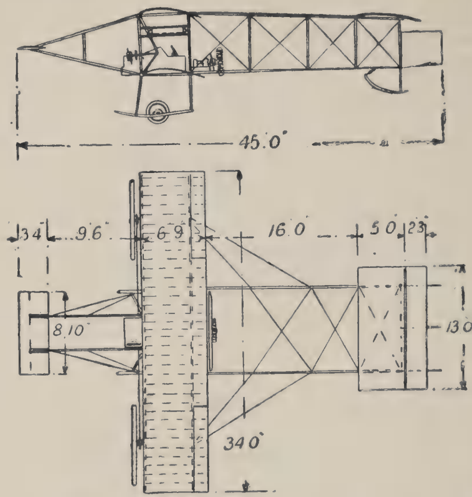


Fig. 36.—Short Biplane (Double-engined Type).

CODY

Biplane, Non-lifting Tail

Span - - - - -	43 ft.
Overall length - - -	37 ft. 9 in.
Area of main planes - -	430 sq. ft.
,, elevators - -	60 ,,
,, fixed tail plane -	10 ,,
,, rudders - -	30 ,,
Aspect ratio of main planes	7·8
Engine - - - -	120 H.P. Austro-Daimler.
Control - - - -	Rudders actuated by horizontal wheel on pivoted column, which is moved sideways for warping and to and fro to work elevators.
Material - - - -	Struts of spruce, skids of hickory, and long spars of bamboo.

This is the machine which was recently successful in the British Military Competition. The most distinctive feature is the divided front elevator, the halves of which are worked in opposite directions to maintain the lateral balance, in conjunction with the warping of the main planes. The fabric used is pegamoid.

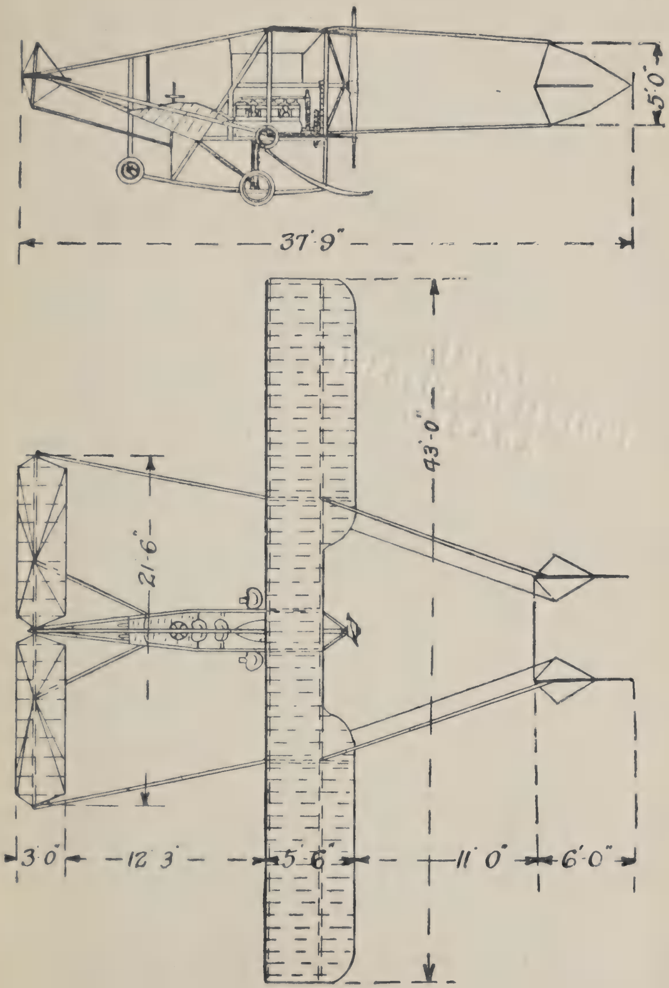


Fig. 37—Cody Biplane.

A TABLE TO ILLUSTRATE THE DEVELOPMENT OF THE DIRIGIBLE

Year.	Name of Dirigible.	Dimensions of Envelope.						Ballonets.	Remarks.
		Length.		Diameter.		Volume.			
		Metres.	Feet.	Metres.	Feet.	Cub. M.	Cub. Ft.		
1783	Meusnier*	...	...	...	...	9,900	349,668	1	Manually driven.
	Giffard—								
1858	No. 1*	44·0	144·3	12·0	39·36	2,500	88,300	...	Steam engine driven.
1855	No. 2*	70·0	229·6	10·0	32·8	3,200	113,024	...	,, ,, ,,
1870	Dupuy de Lôme*	36·1	118·4	14·84	48·7	3,454	121,995·3	1	Manually driven.
1872	Hähnlein†	50·4	165·3	9·2	30·2	2,408	85,050·5	1	Gas engine driven.
1883	Tissandier*	28·0	91·8	9·2	30·2	1,000	35,320	1	Electrically driven.
1884	Renard-Krebs*	50·42	165·4	8·4	27·6	1,864	65,836·5	1	,, ,, one elevator.
1897	Schwarz†	47·5	155·8	12·0	39·36	3,697	130,578	...	Two screws for steering, and one screw for elevator. Gas engine.
	The Petrol Engine Driven Dirigible								
	Santos Dumont—								
1898	No. 1*	25	82·0	3·5	11·5	180	6,357·6	1	... ...
1899	,, 3*	20	65·6	7·5	24·6	500	17,660	...	... ...
1900	,, 4*	39	128·0	5·1	16·7	420	14,834·4	1	... ...
1900	,, 5*	33	108·2	5·0	16·4	550	19,426	1	... ...
1900	Zeppelin—No. 1†	128	419·8	11·65	38·2	11,300	399,116	...	... ...
	Santos Dumont—								
1901	No. 6*	33	108·2	6·0	19·6	630	22,251·6	1	... ..
1901	,, 7*	60	196·8	7·0	23·0	1,257	44,397·2	1	... ...

	Santos Dumont—									
1901	No. 9* - -	15·12	49·6	5·2	17·1	216	7,629·1	1	...	...
1901	,, 10* - -	48	157·4	8·5	27·9	2,010	70,993·2	2	...	...
1901	Deutsch de la Meurthe*	60	196·8	8·0	26·2	2,000	70,640	...	...	...
1901	Rozé* - - -	45	147·6	7·5	24·6	2,800	98,896	(?)	...	...
1901	Bradsky† - -	34	111·5	6·1	20·0	850	30,022	...	...	...
1902	Severo‡ - - -	30	98·4	12·0	39·36	2,400	84,768	...	...	...
1902	Lebaudy (Julliot)*	58	190·2	9·8	32·1	2,284	80,670·8	1	...	...
1902	Spencer§ - -	23	75·4	6·0	19·6	1,860	65,695·2	1	...	...
1904	Julliot "Patrie" * -	60	196·8	10·8	35·4	3,250	114,790	1	...	...
1905	Zeppelin—No. 2† -	128	419·8	11·70	38·4	11,430	403,707·6	...	...	...
1906	"Ville de Paris"* -	62	203·3	10·5	34·4	3,200	113,024	1	...	...
1906	Comte de la Vaulx*	32·5	106·6	6·5	21·3	720	25,430·4	1	...	...
1906	Parseval—No. 1† -	48	157·4	8·7	28·5	2,500	88,300	2	...	...
1907	Santos Dumont—No. 16* - -	21	68·9	3·0	9·8	90	3,178·8	1	...	...
	Zeppelin—									
1908	No. 3† - -	136	446·0	13·0	42·6	15,000	529,800	..	...	...
1908	,, 4† - -	136	446·0	13·0	42·6	15,000	529,800	...	...	...
1908	Julliot "La Republique"* - -	61	200·0	10·8	35·4	3,700	130,684	1	...	...
1908	Malécot* - -	33	108·2	7·3	23·9	1,054	37,227·3	1	...	...
1908	Clement-Bayard* -	46·25	151·7	10·58	34·8	3,500	123,620	2	...	...
1908	Parseval—No. 2† -	58	190·2	9·5	31·1	3,800	134,216	2	...	...
1908	Major Gross† - -	40	131·2	12·0	39·36	1,800	63,586	1	...	...

* French. † German.

‡ Spanish. § English.

Fig. 38.—The Development of the Dirigible.

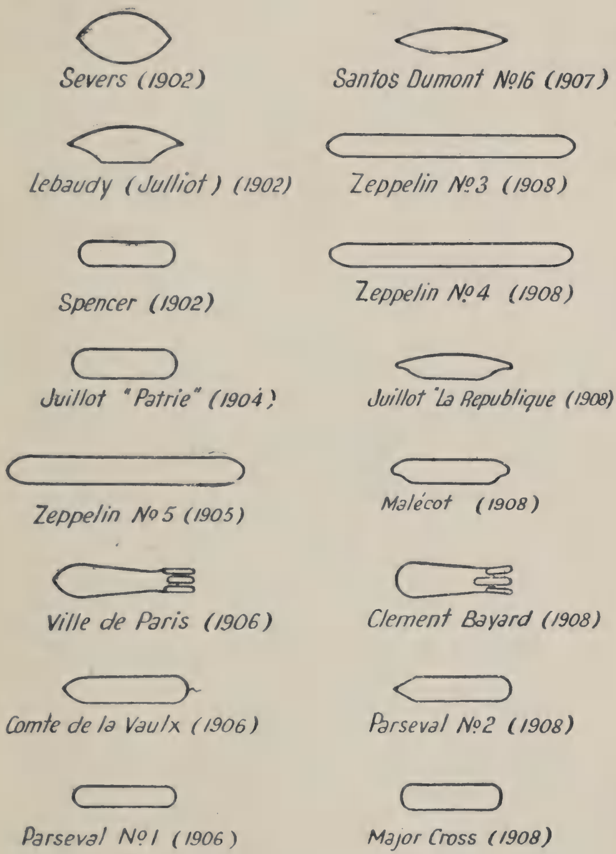


Fig. 39.—The Development of the Dirigible.

DIVISION VI

PILOTING AND AERIAL NAVIGATION

PILOTING AN AEROPLANE

THE only road to proficiency is *practice*, as in other sports. But if certain underlying principles are well understood, the period of learning can be shortened, and the preliminary lessons more quickly turned to advantage.

In the best schools the pupil is taken in the first place for long passenger flights in order to get accustomed to the sensation of being in the air. On some school machines dual control levers are fitted, so that the beginner in the initial stages merely allows his hands to follow the movements of the levers which are guided by the pilot; then gradually he can start controlling the machine himself, any wrong movement being at once corrected, and possible accidents avoided, by the skilled operator who has hold of another lever controlling the same movement. The only objection possibly that might be raised to this method is that when eventually the learner flies by himself he continually keeps his levers moving slightly, thus producing a longitudinal oscillation in the machine. This appears to be due to slight nervousness owing to the fear of carrying a movement too far, or not far enough.

In the early stages when the machine begins to depart from its even course there is very often little time for thought as to the method of righting it. For this reason the control of many machines is arranged so that the instinctive movements of the pilot operate the balancing mechanism so as to regain stability. The first thing necessary, therefore, is to examine the controls of the machine, and to ascertain whether the movements of the levers and guide-wheels, with which the machine is equipped, correspond to those which might be expected. If the vertical rudder, for example, is controlled by a steering wheel, it should be arranged in the same way as the wheel of a motor car. This also will correct canting of the machine, since the pilot will naturally lean to the rising side, and his tendency will be to pull that side of the wheel towards him. Again, with

regard to the elevator: if the front of the machine dips downwards, the pilot will naturally lean back, and in so doing will tend to pull the lever or wheel backwards. This method of controlling the elevator is largely used, the steering wheel being moved bodily backwards and forwards. If we take as an instance the Voisin biplane, it will be found that both these instinctive movements are made use of. The steering device consists of a wheel, the turning of which causes the rudder to move to the right or left as required, while the movement of this wheel as a whole, forward or backward, causes the elevator to turn down or up respectively.

Before starting a flight the statical balance of the machine should be adjusted, as otherwise one wing may have to be warped, or one aileron held down, to an extent which may allow insufficient further movement in case of need.

Although on many machines there is little to affect the balance while on the ground, it is an important matter on those, for instance, of the type in which the engine is placed on one side, and is balanced laterally by the weight of the pilot.

The next thing to be done is to acquire lateral and longitudinal control while "rolling," or running along the ground. For this it is necessary to consider the action of the elevator, the rudder, and the wing-warping arrangements or ailerons.

The chief point in the working of the elevator is the small degree of movement and the lightness of touch required. Since an aeroplane can only rise by means of extra power developed by the engine, if the elevator is raised too much the consequence will be that the machine will rise steeply, lose its velocity, and slide backwards on to its tail. This is a common mistake in the early stages, and one that may easily be fraught with serious consequences. With regard to the lateral movements, it must be remembered that when an aeroplane turns it leans over towards the centre of the curve; so that when a wing rises unduly for any reason, it can be corrected by steering towards the raised wing. Another method of correcting the roll is to pull down the aileron attached to the lower wing; either or both of the methods may be used simultaneously.

When control of the machine while rolling has been learnt, the next stage is making straight flights. The safest way to rise, if the construction of the machine permits, is simply to allow it to "float off" as the speed increases, without moving the elevator at all, thus preventing the possibility of a backward slide.

If the machine is a monoplane the tail will usually rise first as the speed increases: when a sufficient velocity is reached the elevator is moved so as to depress the tail, thus increasing the angle of incidence of the main planes and bringing the front wheels off the ground. The tail then follows and the machine is in flight. As it rises the angle of ascent must be kept small, as the engine has probably not reached its full output and there is danger of the machine sliding backwards as described above.

When in the air the balance must be kept as previously explained,

but the direction will probably at first be somewhat uncertain. This is to be explained by considering for a moment the methods of keeping the machine on an even keel.

The effect of pulling down the wing flap or of warping the wing is to raise the end of the wing and at the same time to slow it, as more work has to be done to throw downwards a larger quantity of air. Steering towards the raised wing has the opposite effect of accelerating the lower one, and practice is the only method of so proportioning the two modes of balance that the direction is kept constant. Observation of an experienced pilot will show that these oscillations have little more effect on his course than is produced by the continuous and subconscious movements of the front wheel made by the rider of a bicycle in order to keep his balance. Luckily the change of position of a well-designed machine is gradual, and so the aviator has ample time in which to bring it back to its normal position. In fact, if the control is too rapid and not stopped as soon as the aeroplane commences to respond, an oscillating movement might be set up, which, when superimposed on the general movement of the aeroplane, might be very difficult to suppress. The upward or downward turning of the elevator must similarly be very delicately controlled, to avoid objectionable longitudinal oscillations.

The chief rule to be remembered in alighting is that the machine should finish up with a horizontal velocity, with as little downward movement as is possible. Here again the type of machine makes a difference as to the exact method. Experienced pilots of lifting-tail monoplanes often allow them to "pancake" for the last few inches as the speed decreases, while the non-lifting tail machines are at once brought down on to their front wheels. When sufficient experience has been gained to allow the engine to be stopped while the machine is still in the air, in order to "plane" down, the design of the aeroplane will determine the procedure to be adopted. Ordinarily there is no great difficulty; in the Farman type, however, with the engine behind the main planes and with a lifting tail, the pilot, immediately the engine stops, must manipulate his elevator so as to start a dive, because of the dropping of the tail due to the absence of the propeller blast.

When straight flights can be satisfactorily accomplished, turning can be attempted. For turning with a small radius a force must be introduced to counteract the centrifugal force caused by the turn. This is effected by "banking" the aeroplane; on most machines it is to some extent automatic, due to the provision of the small fixed vertical planes known as "blinkers." If the automatic banking is insufficient it must be increased by lowering the aileron on the outside of the curve. It is of course possible to calculate the angle at which a machine should turn with the least tendency to "side-slip," but there are quite possibly unknown factors which vitiate the value of the calculation. A table is given for what it may be worth (p. 118)

Flying in a Wind

As far as the actual management of the machine in the air is concerned practice is the only teacher. The faster the machine is, the safer will it be in a wind.

The start must be made with the wind either ahead or astern, and since in the latter case the rise will be very slow, the former method is usually adopted. Once off the ground, if the wind is steady, no serious difficulty will be met with until a turn through 180° is attempted. Obviously the speed of the machine relative to the air must be maintained, and in a turn from up wind to down wind this means increasing the speed of the machine relative to the ground by an amount double the velocity of the wind. The usual method is to rise just before making the turn, open out the engine, and swoop downwards as the turn is made. When alighting the aeroplane must again be brought head to wind. To do this, the apparent motion of the ground, which will be at an angle to the course of the aeroplane, must be noted, and the machine turned *away* from the direction of this motion. *I.e.*, in the figure the turn must be made as shown by the arrow. Failure to come down head on to the wind may mean an awkward spill, more especially if the landing gear is not fitted with "castor" wheels.

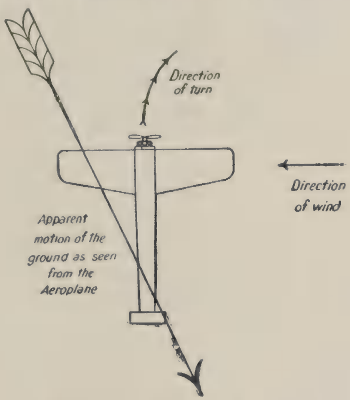


FIG. 40.—Handling in a Wind.

AERIAL NAVIGATION

Various instruments are useful, and some indispensable, for long cross-country flights. The most important are the following :—

The **Tachometer**, for measuring the rate of engine revolution.

The **Level** or **Gradometer**, to measure the inclination of the machine to the horizontal. This will be particularly useful in clouds or fog where the whole of the machine is not in view at once.

The **Aneroid Barometer**, to measure the height. This is dealt with in the "Meteorological" section, p. 125.

A **Speed Recorder**, to find the speed of the aeroplane relative to the ground. A form of this instrument is on the market, and is referred to below.

The **Anemometer**, or other speed recorder, to find the speed relative to the wind.

The **Compass**, to set and steer a course as found from a map.

In addition, of course, the best available **Maps** should be carried, preferably in strip form, and a weather-tight roll holder provided, so that the route can easily be traced. A pair of good **Binoculars** would also probably prove useful.

The Joanneton speed recorder consists of a mirror connected to a pointer moving over a quadrant, upon which is a table of heights and speed. The observer views the image of a fixed object on the ground in the mirror by the aid of a small fixed telescope on the apparatus, and keeps the object in sight for a given time by turning the mirror. The speed of the aeroplane is then obtained from the position of the pointer on the graduated quadrant. As will be seen from the description, the instrument is one rather for the passenger than for the pilot ; but it is not improbable that a passenger will often be entrusted with the care of most of the navigating instruments.

With regard to the compass, the necessary precautions to be taken will be better understood if the principles and construction of the instrument are first examined. It consists of a flat circular card, the edge of which is divided into points, half points, and quarter points, and also into 360 degrees (see diagram on p. 111 and table on p. 112). To the under side of the card are attached one or more light magnetic needles, and the whole is pivoted on a centre which in the best instruments consists of an iridium pivot bearing on an agate or sapphire cap. The card is enclosed in a cylindrical case, which for an aeroplane should be filled with liquid, and the case is hung on gimbals. Opinions seem to differ to some extent as to the advisability of fitting gimbals, but the weight of opinion is in their favour. The compass should be insulated as far as possible from shocks and vibration.

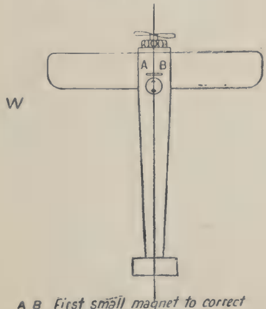
The point of the compass marked "N." does not point to the true north, but to the magnetic north. The angle between the two directions varies in different parts of the world at different times : in England it is at present about 15°. That is to say, the compass points in a direction 15° west of true north. This is called the **magnetic variation.**

Movable masses of iron or steel in close proximity to the compass will seriously affect its reading. Control levers are very often bad

offenders in this respect, and if they are anywhere near the compass, should be made of non-magnetic material, such as manganese steel, duralumin, or bronze. It was recently mentioned that the steel clasp of a pilot's belt had a similar bad effect. Errors due to fixed pieces of iron in the neighbourhood of the compass can be compensated for as follows :—

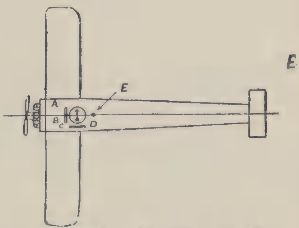
Semicircular Deviation.—This is of two kinds, (*a*) that due to any sub-permanent magnetism in the iron and steel used in the construction of the aeroplane, (*b*) that due to magnetism induced by the earth in any vertical masses of iron. To correct for (*a*) place the aeroplane on an even keel in the flying position, and with its long axis lying correct magnetic N. and S. Place a small permanent magnet either before or behind the compass at right angles to the meridian, with its N. pole on the side of the meridian to which the compass points, and move it towards or away from the compass until the latter shows correct magnetic N. and S. (Fig. 41).

Now place the machine on an even keel and in its flying position as before, but with its longitudinal axis lying correct magnetic E. and W. If the compass now shows other than exactly E. or W. under the lubber line, place, on either side of the compass, a second magnet at right angles to the first one, with its centre on a perpendicular from the centre of the compass, and its N. pole on that side towards which the N. pole of the compass card points. Move this magnet towards or from the compass until the position of the aeroplane as shown by the compass is exact magnetic E. and W. (Fig. 42).



A B *First small magnet to correct for semicircular deviation*

FIG. 41.



C D *Second small permanent magnet to correct semicircular deviation*
E *Vertical bar of soft iron to correct semicircular deviation*

FIG. 42.

These two adjustments are sufficient to correct any error due to permanent magnetisation of vertical iron or steel portions of the aeroplane. The next thing is to correct for (*b*) above. This is

done with the machine still in the magnetic E. and W. position: a vertical bar of soft iron is placed on the fore-and-aft line through the centre of the compass, on the opposite side of the compass to that towards which the **N.** on the card tends to point. The bar is moved to and from the compass until the aeroplane lies exact magnetic E. and W., as shown by the needle (Fig. 42).

Quadrantal Deviation.—This is caused by magnetism induced by the earth in horizontal masses of iron or steel. The aeroplane is placed with its longitudinal axis either N.E. and S.W., or N.W. and S.E., and soft iron balls are placed on each side of the compass on a line through its centre at righ angles to the longitudinal axis of the machine, and are moved toward or away from the compass until the indication of its needle is correct (Fig. 43.)

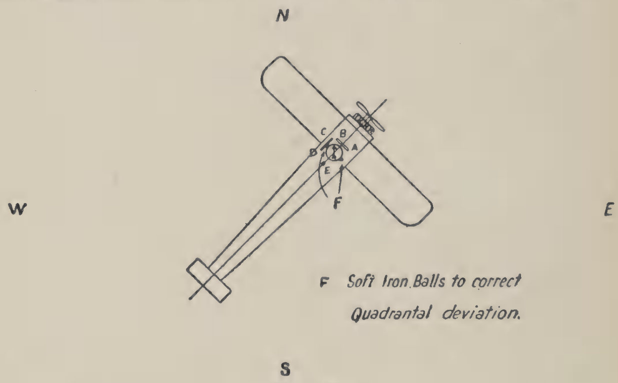


Fig. 43.

In addition to the above there is an error introduced when the aeroplane rolls. This can be corrected by placing a vertical magnet directly underneath the centre of the compass.

When a compass has been thus corrected, although it will be practically exact on the points tested, there will be small errors on the other points. For the comparatively short distances for which a compass is likely to be used on an aeroplane, these errors are almost negligible; but if necessary it is a simple matter to compile a "deviation table" from observation, showing the error of the compass on the principal points.

The Compass Adjuster.—The various corrections referred to in the preceding paragraphs are usually made by a professional compass adjuster, who is accustomed to similar work in the case of sea-going vessels, which likewise have to get their compasses adjusted from time to time.

To Steer a Course by Compass.—A mark is made on the case of the compass exactly opposite the N. point on the card when the aeroplane is lying magnetic N. and S. This mark is known as the "lubber line," or "lubber point." To follow a given course, say N.W. by N., ¼ N., the aeroplane is turned until the corresponding point on the card is opposite the lubber line; the two marks must then be kept in line until a different course is required. In the "Clift" compass an adjustable pointer is provided, which is attached to the card and can be rotated to any required position. This pointer is set to the course required, and all that is then necessary is to keep it opposite the lubber line. The same attachment can be illuminated so that a white light shows when the course is correct, a red light when the machine is off the course to the left, and a green light when off to the right; it also allows the card to be lifted off its pivot when not in use, thus preventing undue wear of the centres. It has been suggested that luminous paint should be used to facilitate steering at night.

An allowance for leeway due to side winds must be made; experience with the same machine in different winds will enable the pilot to judge the leeway he is making with a considerable degree of accuracy, by noting the apparent direction of travel of the ground. Probably some simple instrument will be devised to estimate the leeway by observation of this direction.

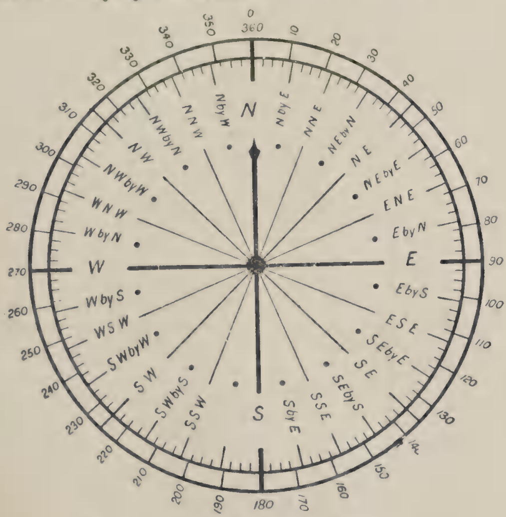


FIG. 44.—Points of the Compass.

POINTS OF THE COMPASS

				Points.	Angle with Meridian.		
					Degs.	Mins.	Secs.
N.	N.	S.	S.	0	0	0	0
N., ¼ E.	N., ¼ W.	S., ¼ E.	S., ¼ W.	¼	2	48	45
N., ½ E.	N., ½ W.	S., ½ E.	S., ½ W.	½	5	37	30
N. by E., ¼ N.	N. by W., ¼ N.	S. by E., ¼ S.	S. by W., ¼ S.	¾	8	26	15
N. by E.	N. by W.	S. by E.	S. by W.	1	11	15	0
N. by E., ¼ E.	N. by W., ¼ W.	S. by E., ¼ E.	S. by W., ¼ W.	1¼	14	3	45
N.N.E., ½ N.	N.N.W., ½ N.	S.S.E., ½ S.	S.S.W., ½ S.	1½	16	52	30
N.N.E., ¼ N.	N.N.W., ¼ N.	S.S.E., ¼ S.	S.S.W., ¼ S.	1¾	19	41	15
N.N.E.	N.N.W.	S.S.E.	S.S.W.	2	22	30	0
N.N.E., ¼ E.	N.N.W., ¼ W.	S.S.E., ¼ E.	S.S.W., ¼ W.	2¼	25	18	45
N.N.E., ½ E.	N.N.W., ½ W.	S.S.E., ½ E.	S.S.W., ½ W.	2½	28	7	30
N.E. by N., ¼ N.	N.W. by N., ¼ N.	S.E. by S., ¼ S.	S.W. by S., ¼ S.	2¾	30	56	15
N.E. by N.	N.W. by N.	S.E. by S.	S.W. by S.	3	33	45	0
N.E. by N., ¼ E.	N.W. by N., ¼ W.	S.E. by S., ¼ E.	S.W. by S., ¼ W.	3¼	36	33	45

N.E., ½ N.	N.W., ½ N.	S.E., ½ S.	S.W., ½ S.	3½	39	22	30
N.E., ¾ N.	N.W., ¾ N.	S.E., ¾ S.	S.W., ¾ S.	3¾	42	11	15
N.E.	N.W.	S.E.	S.W.	4	45	0	0
N.E., ¼ E.	N.W., ¼ W.	S.E., ¼ E.	S.W., ¼ W.	4¼	47	48	45
N.E., ½ E.	N.W., ½ W.	S.E., ½ E.	S.W., ½ W.	4½	50	37	30
N.E. by E., ¼ N.	N.W. by W., ¼ N.	S.E. by E., ¼ S.	S.W. by W., ¼ S.	4¾	53	26	15
N.E. by E.	N.W. by W.	S.E. by E.	S.W. by W.	5	56	15	0
N.E. by E., ¼ E.	N.W. by W., ¼ W.	S.E. by E., ¼ E.	S.W. by W., ¼ W.	5¼	59	3	45
E.N.E., ½ N.	W.N.W., ½ N.	E.S.E., ½ S.	W.S.W., ½ S.	5½	61	52	30
E.N.E., ¼ N.	W.N.W., ¼ N.	E.S.E., ¼ S.	W.S.W., ¼ S.	5¾	64	41	15
E.N.E.	W.N.W.	E.S.E.	W.S.W.	6	67	30	0
E.N.E., ¼ E.	W.N.W., ¼ W.	E.S.E., ¼ E.	W.S.W., ¼ W.	6¼	70	18	45
E.N.E., ½ E.	W.N.W., ½ W.	E.S.E., ½ E.	W.S.W., ½ W.	6½	73	7	30
E. by N., ¼ N.	W. by N., ¼ N.	E. by S., ¼ S.	W. by S., ¼ S.	6¾	75	56	15
E. by N.	W. by N.	E. by S.	W. by S.	7	78	45	0
E. by N., ¼ E.	W. by N., ¼ W.	E. by S., ¼ E.	W. by S., ¼ W.	7¼	81	33	45
E., ½ N.	W., ½ N.	E., ½ S.	W., ½ S.	7½	84	22	30
E., ¼ N.	W., ¼ N.	E., ¼ S.	W., ¼ S.	7¾	87	11	15
E.	W.	E.	W.	8	90	0	0

An Approximate Method of Finding True North is as Follows :—

In the Northern Hemisphere.—Hold the watch horizontally, face upward, and point the hour hand at the sun. Then a line from the centre of the dial to a point half-way between the figure XII. and the hour hand will be approximately a south line.

In the Southern Hemisphere.—Hold the watch as above, but point the line from the centre of the dial to the figure XII. at the sun. Then the line found as above is approximately a north line.

It should be remembered that the method is a rough one, and becomes almost useless as the tropics are approached, although more reliable for higher latitudes.

To Find True North by the Stars

The "pointers" of the Great Bear are in a line with the Pole Star, as shown in the sketch.

FIG. 45.

The Great Bear revolves about the Pole Star, so that it will be found lying in different positions at different times; when it is so placed that the star "Zeta" is either directly above or directly below the Pole Star, the direction of the latter is true north. At other times there is a small error, which at its greatest amounts to about $1\frac{1}{2}°$.

RULES FOR AVIATION

As in the case of navigation, it is imperative that a code of rules be observed in the steering of airships and aeroplanes, so that the dangers of collision may be avoided. Accordingly the following code has been prepared by the Royal Aero Club :—

Cross-Country Flying

(*a*) Two aircraft meeting each other end on, and thereby running the risk of a collision, must always steer to the right. They must,

in addition to this, pass at a distance of at least 100 m. taken between their nearest adjacent points.

(*b*) Any aircraft overtaking another aircraft is responsible for keeping clear, and must not approach within 100 m. on the right or 300 m. on the left of the overtaken aircraft, and must not pass directly underneath or over such overtaken aircraft.

The distance shall be taken between the nearest adjacent points of the respective aircraft. In no case must the overtaking aircraft turn in across the bows of the other aircraft after passing it so as to foul it in any way.

(*c*) When any aircraft are approaching one another in cross directions, then the aircraft that sees another aircraft on its right-hand forward quadrant must give way, and the other aircraft must keep on its course at the same level till both are well clear.

Exception

In the case of dirigibles the distance of 100 m. prescribed above shall be increased to 500 m.

Flying Grounds

The following special regulations apply only to flying grounds :—

(*d*) Two aircraft meeting each other end on, and thereby running the risk of a collision, must always steer to the right. They must, in addition to this, pass at a distance of at least 30 m. taken between their nearest adjacent points.

(*e*) Any aircraft overtaking another aircraft is responsible for keeping clear, and must pass outside the overtaken craft at least a clear 30 m. distance. In no case must the overtaking aircraft turn in across the bows of the other aircraft after passing it so as to foul it in any way. The distance shall be taken between the nearest adjacent points of the aircraft.

In these regulations the term "foul" shall include the giving of dangerous backdraught to another aircraft.

RULES FOR JUDGING DISTANCE

Distances are **overestimated** :—

1. When the background and the object under observation are of the same colour.

2. When the object is in the shade, or is only partially seen.

3. In mist or failing light.

Distances are **underestimated** :—

1. When the background and the object under observation are of different colours.
2. When the sun is behind the observer, or when the light is very strong.
3. When the object is seen over water or a deep chasm.
4. When the object is very large.
5. Always when looking downwards from the air, or in looking upwards.

Constant practice is essential to become proficient at rapidly judging distances.

PHYSIOLOGICAL EFFECTS OF FLYING

There are two chief sets of effects to be noticed : firstly, the "air sickness" due to the rolling and pitching of the aeroplane when flying in a wind. This is merely a form of sea sickness, and springs from the same causes. Secondly, there are various symptoms which follow on very high flights, and are essentially the same as the "mountain sickness" experienced in high altitudes in such places as the Andes. These are chiefly due to deficiency of oxygen, owing to the rarefied condition of the atmosphere in its upper levels.

According to Dr G. von Liebig, the following symptoms are felt at great heights : (1) Palpitation of the heart, accompanied by an acceleration of its action and throbbing of the arteries ; (2) Shallow breathing, and consequent shortness of breath ; (3) Flickering before the eyes ; (4) Faintness ; (5) Coldness of the extremities ; (6) Difficulty in eating or in drinking strong stimulants.

At still greater altitudes, the pressure in the veins and capillaries is so increased as to cause exudations of blood from the mucous membranes of the mouth, nose, and eyes ; the brain becomes affected because of the deficiency of oxygen in the arterial blood, and causes dulness and dejection, loss of the various senses, and eventually unconsciousness ; and there is the danger of frostbite because of the extreme cold. The ear drum has been known to crack at 10,000 ft. The experience of Glaisher in one of his balloon ascents was that at 18,000 ft. his hands became livid, and at increasing heights he successively lost the power of moving his limbs, his eyesight, power of speech, hearing, and consciousness, only recovering when the balloon again descended.

These serious symptoms are not evident except at heights to which it would rarely be necessary or even possible for an aeroplane to reach. A recent communication to the *Gazette Hebdomadaire des Sciences Médicales de Bordeaux* stated that the effects experienced after a height of 4,000 to 6,500 ft. has been reached are lividity of the extremities, slight headache, a ringing in the ears, and congestion of the under surface of the eyelid. The pulse is slightly accelerated, and the blood pressure is always increased after a high flight.

Various remedies have been suggested. The inhalation of oxygen is one that has been frequently used by balloonists and others, and is known to fulfil its purpose. Others which could be used by aviators are garlic and capsicum, the smell of which is frequently sufficient to moderate the symptoms referred to above. Precautions which should be practised are the taking of nourishment during a high flight in small but frequent quantities, and to descend slowly, since the lungs and circulatory apparatus have to adjust themselves to a different air pressure, and are exposed to dangerous fatigues during high flights. More than one fatal accident is in all probability due to a too rapid descent.

TABLE SHOWING DISTANCES AT WHICH OBJECTS CAN BE SEEN ACCORDING TO THEIR RESPECTIVE ELEVATIONS AND THE ELEVATION OF THE EYE OF THE OBSERVER

(*This table applies to heights above the sea or other flat surface*)

$$D = 1.42\sqrt{H}$$

Height in Feet.	Distance in Miles.	Height in Feet.	Distance in Miles.
5	3·16	200	20·04
10	4·48	300	24·54
15	5·50	400	28·34
20	6·34	500	31·62
25	7·10	600	34·78
30	7·76	700	37·57
35	8·40	800	40·16
40	8·98	900	42·60
45	9·51	1,000	44·72
50	10·02	1,500	54·99
60	10·97	2,000	63·37
70	11·83	2,500	71·00
80	12·67	3,000	77·61
90	13·44	3,500	84·01
100	14·14	4,000	89·68
150	17·35	5,000	100·40

Thus, an object 20 ft. high will be visible to the observer whose eye is elevated 300 ft. above the water or other flat surface, 30·88 miles.

20 ft. elevation, distance visible - - -	6·34 miles
300 ,, ,, ,, ,, - - -	24·54 ,,
	30·88 miles.

THEORETICAL ANGLES OF HEEL FOR VARIOUS SPEEDS AND RADII OF TURNS

Radius of Turn in Yards.	Velocity Relative to Wind in Miles per Hour.				
	20	40	60	80	100
	Angles of Heel.				
	Degs.	Degs.	Degs.	Degs.	Degs.
20	24	61	...	...	...
40	12	42	64	...	...
60	8	31	52	67	...
80	6½	24	45	61	...
100	5	20	39	55	66
200	2½	10	22	35½	48
300	1¾	7	15	25	36
400	1½	5	11	19½	29

LEGAL

Legal text-books do not at present throw any light upon the position of an aeroplane in law, which is of course due to the fact that it does not proceed along a highway. In the case of locomotion of any form along public roads, the whole matter is closely hedged in with rules of law, the outcome of centuries of experience, so that all questions of liability for damage done are fairly easily settled.

Trespass

There is a case on record in which it was shown to be a trespass to pass over a man's land in a balloon since a man owns his land *usque ad cœlum.*

If in descending, injury is done to property, the aviator may be sued in *tort.*

Liability of an Aviator

If an aviator lands in a place where the public have access, and does damage to some person or persons, he is of course liable under common law. It is not such an easy point to determine the question of liability when the person run down is trespassing on private grounds, assuming that the aviator is also a trespasser. As regards such accidents at an aviation meeting, apparently the aviator is not held responsible, as is indicated in the next paragraph.

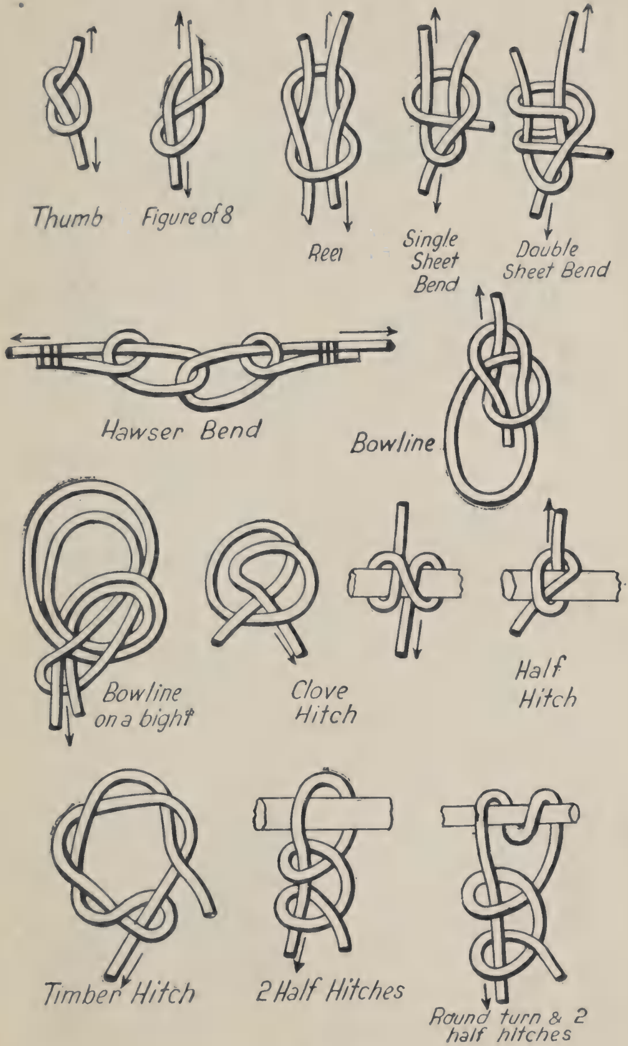

Thumb
Figure of 8
Reel
Single Sheet Bend
Double Sheet Bend
Hawser Bend
Bowline
Bowline on a bight
Clove Hitch
Half Hitch
Timber Hitch
2 Half Hitches
Round turn & 2 half hitches

FIG. 46.

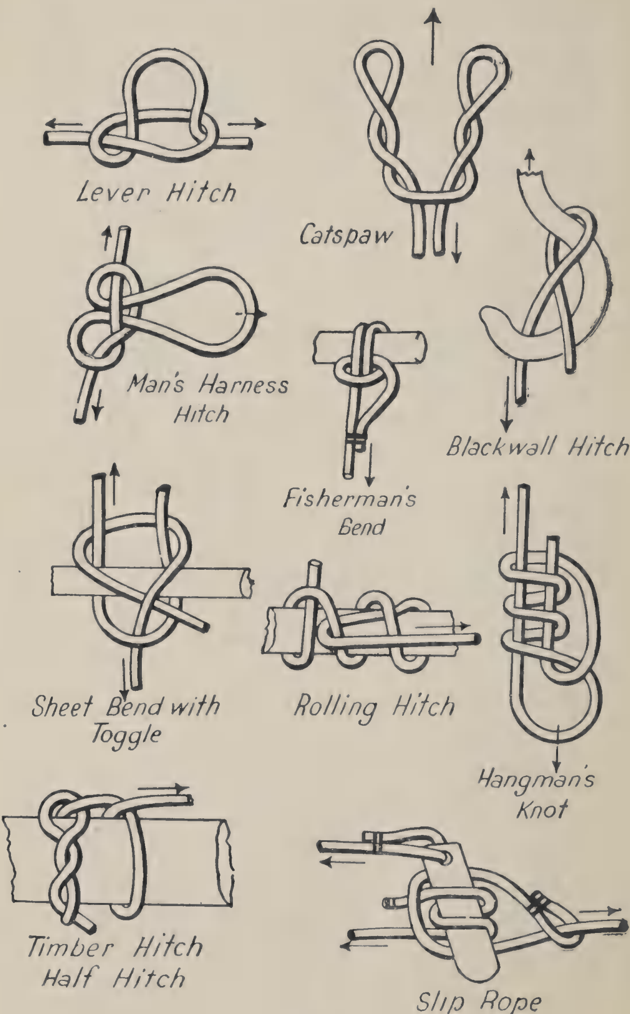

Lever Hitch
Catspaw
Man's Harness Hitch
Fisherman's Bend
Blackwall Hitch
Sheet Bend with Toggle
Rolling Hitch
Hangman's Knot
Timber Hitch
Half Hitch
Slip Rope

FIG. 47.

Liability of Aviation Meeting Organisers

No liability accrues to the organisers of aviation meetings for an accident happening to a spectator, as is indicated from the following, which is abstracted from a book entitled "The Law of Torts": "The breach of duty which will render an owner of premises liable to a person coming there on business consists either in (1) neglecting to give warning of hidden sources of danger which are known to him; or in (2) omitting to take proper precautions to acquire knowledge of the danger, and having acquired it, to give proper warning. As towards a bare licensee not coming on business, the owner is liable only for negligence of the first kind. But as towards either class of licensees, the owner having given due warning, is free from all responsibility."

Aerial Navigation Acts, Rules, and Orders

The Acts, Rules, and Orders dealiug specifically with aviation matters are as follows:—

Aerial Navigation Act, 1911.
Aerial Navigation Act, 1913.
Statutory Rules and Orders, 1913, *No.* 228.
Statutory Rules and Orders, 1913, *No.* 243.
Order dated 1913 re *Aerial Navigation Act*, 1913.
Statutory Rules and Orders, 1914, *No.* 725.
Statutory Rules and Orders, 1914, *No.* 726.

KNOTS

These knots are used as follows:—

To make a knot on a rope.—Thumb knot, figure-of-eight knot.
To make a nonslipping loop on the end of a rope.—Bowline.
To make a nonslipping loop in the middle of a rope.—Bowline on a bight.
To make a slip knot.—Hangman's knot.
To join two ropes.—
Same sized ropes—Reef knot, hawser bend.
Different sized ropes—Single-sheet bend.
Wet ropes—Double-sheet bend.
To secure a rope to a spar.—Clove hitch, round turn and two half hitches, two half hitches, timber hitch, half hitch, fisherman's bend.
To secure a rope rapidly to a hook.—Blackwall hitch.
To secure a hook to the middle of a rope.—Catspaw.
To secure a spar across a rope.—Lever hitch.
To make a loop on a drag-rope.—Man's harness hitch.
To fix a rope "endways on" to a spar.—Timber hitch and half hitch.
To fix a rope "endways on" to a larger rope.—Rolling hitch.

DIVISION VII

METEOROLOGICAL DATA

THE ATMOSPHERE

The atmosphere consists mainly of a mixture of two gases, oxygen and nitrogen, in the proportion by volume—

Oxygen - - - - -	21 per cent.
Nitrogen - - - -	79 ,,

or, by weight—

Oxygen - - - - -	23 per cent.
Nitrogen - - - -	77 ,,

It also contains a varying small quantity of carbonic acid gas, equal to about 0·03 per cent. in the open country, as well as minute quantities of several inert gases. The amount of water vapour in suspension varies with the temperature, being greater when the latter is high.

The atmosphere extends appreciably to at least 50 miles from the earth's surface, and probably in an extremely rarefied condition to 200 miles ; one-half of its total mass is below 15,000 ft.

The pressure of the atmosphere at sea level is 14·7 lbs. to the square inch, or 2,116 lbs. to the square foot, at 32° F. ; it varies with the height above sea level, as shown in the table on p. 126.

The temperature of the atmosphere decreases on an average about 1° F. for every 273 ft. above the earth's surface. Mr Glaisher, in his balloon ascents, found unequal variations on passing through different air strata, once finding a comparatively warm current at 14,000 ft. ; an alternation of warm and cold currents was sometimes met with. On an average, however, the temperature decreases much as given above, until, at an altitude of something over 25,000 ft., it becomes practically constant.

The following table is given by Berson :—

Altitude in Feet.	Mean Temperature. ° F.	Decrease per 1,000 Feet.	Altitude in Feet.	Mean Temperature. ° F.	Decrease per 1,000 Feet.
0	50	...	16,000	3½	3
2,000	45	2½	17,000	0	3½
4,000	40	2½	18,000	– 4	4
6,000	34	3	20,000	–12	4
8,000	28	3	22,000	–20	4
10,000	22	3	24,000	–28	4
12,000	15½	3	26,000	–36	4
14,000	9½	3	28,000	–44	4

Air liquefies at a temperature of –220° F. under a pressure of 574 lbs. per square inch.

The weight of dry air is given by—

$$W = 2{\cdot}709\frac{P}{T},$$

Where W = weight of 1 cub. ft. of air in lbs.,
P = pressure in lbs. per square inch (including atmosphere),
T = absolute temperature (= ° F. + 461).

WEIGHT OF DRY AIR AT DIFFERENT PRESSURES AND TEMPERATURES

Temperature, ° F.	–40	–20	0	20	40	60	80	100
Barometer Reading, In.								
30·5	·0964	·0920	·0880	·0844	·0810	·0779	·0750	·0723
30	·0948	·0905	·0866	·0830	·0797	·0766	·0737	·0711
29·5	·0932	·0890	·0852	·0816	·0784	·0753	·0725	·0700
29	·0916	·0875	·0837	·0802	·0770	·0740	·0713	·0688
28·5	·0901	·0860	·0823	·0788	·0757	·0728	·0701	·0676
28	·0885	·0845	·0808	·0774	·0744	·0715	·0688	·0664
27·5	·0869	·0829	·0793	·0760	·0730	·0702	·0676	·0652
27	·0853	·0815	·0779	·0747	·0717	·0689	·0664	·0641
26	·0822	·0784	·0750	·0719	·0691	·0664	·0639	·0617
25	·0790	·0754	·0722	·0691	·0664	·0638	·0615	·0593
24	·0759	·0724	·0693	·0664	·0638	·0613	·0590	·0569
22	·0695	·0663	·0635	·0608	·0584	·0562	·0541	·0521
20	·0632	·0603	·0577	·0553	·0531	·0511	·0492	·0474
18	·0569	·0543	·0520	·0498	·0478	·0460	·0443	·0427
16	·0506	·0483	·0462	·0443	·0425	·0409	·0394	·0380
14	·0443	·0423	·0404	·0388	·0372	·0358	·0345	·0332
12	·0379	·0362	·0346	·0332	·0319	·0306	·0295	·0284
10	·0316	·0302	·0289	·0277	·0266	·0255	·0246	·0237
5	·0158	·0151	·0145	·0139	·0133	·0128	·0123	·0119

The Barometer

The barometer is used to determine the pressure of the air: by finding the difference in pressure at two places their difference in height above the sea level can be determined.

Let R = reading of barometer at lower station in inches of mercury,

r = ,, ,, upper ,, ,, ,,

T = temperature at lower station in degrees F.

t = ,, ,, upper ,, ,, ,,

K = correction for difference of temperature $(T + t)$.

Then H, the difference in the heights of the stations in feet is given by :—

$$H = 60{,}000\ [\log R - \log r]\ K, \text{ approximately.}$$

Tables giving values of H and K will be found on the following pages.

The Barograph

The barograph is a self-registering barometer. The usual pattern used by aviators works on the aneroid principle, and has two or more boxes coupled up together. The motion of the boxes is recorded by a pen worked by a series of multiplying levers.

It must be remembered in carrying a barograph that the position in which it is placed may affect the reading. It should be hung free of the propeller blast, and should periodically be checked by reference to a mercury barometer.

The Aneroid Barometer

The aneroid barometer consists in principle of a round, flat, exhausted box to which is attached a spring. The motion of the

top and bottom of the box under varying atmospheric pressure is recorded by the spring, which moves a pointer by means of a lever and chain. The figure will explain the action of the instrument.

The spring S rests in gudgeons in the pillars V, V, and is attached to a socket in the top of the box B. Motion of the spring is communicated through the lever L and the bent lever Q to the chain C, which is wound upon the arbor A, carrying the pointer P. When the box is compressed by an increase in the atmospheric

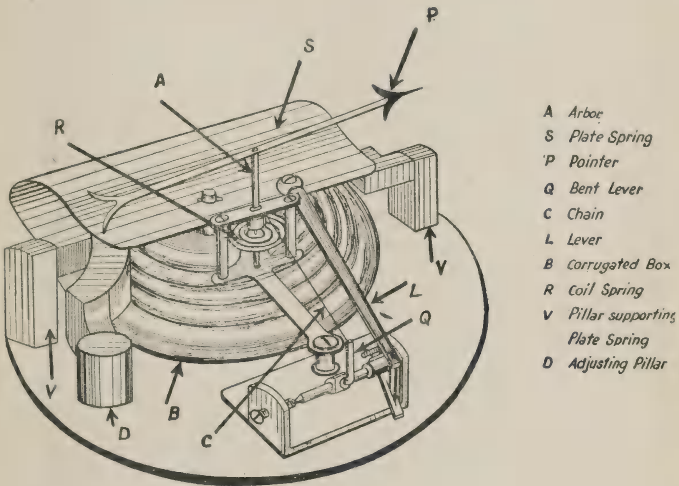


Fig. 48

pressure, the motion of the arbor A winds up the coil spring R; when the pressure decreases, the relaxation of the spring S acting through the levers slackens the chain C, which is made taut again by the unwinding of the coil spring R. The adjusting pillar D is fastened to the spring S, and is moved by a screw passing through the base plate of the instrument, so as to bring the reading of the instrument into accordance with that of a standard mercury barometer.

PRESSURE OF THE ATMOSPHERE CORRESPONDING TO VARIOUS HEIGHTS OF THE BAROMETER

Barometer Reading, Inches of Mercury.	Atmospheric Pressure, Lbs. per Sq. In.	Barometer Reading, Inches of Mercury.	Atmospheric Pressure, Lbs. per Sq. In.	Barometer Reading, Inches of Mercury.	Atmospheric Pressure, Lbs. per Sq. In.	Barometer Reading, Inches of Mercury.	Atmospheric Pressure, Lbs. per Sq. In.
31·5	15·47	27·7	13·60	24·3	11·93	20·0	9·82
31·0	15·22	27·6	13·55	24·2	11·88	19·8	9·73
30·9	15·17	27·5	13·50	24·1	11·83	19·6	9·63
30·8	15·12	27·4	13·46	24·0	11·79	19·4	9·53
30·7	15·07	27·3	13·41	23·9	11·74	19·2	9·43
30·6	15·03	27·2	13·36	23·8	11·69	19·0	9·33
30·5	14·98	27·1	13·31	23·7	11·64	18·5	9·09
30·4	14·93	27·0	13·26	23·6	11·59	18·0	8·84
30·3	14·88	26·9	13·21	23·5	11·54	17·5	8·60
30·2	14·83	26·8	13·16	23·4	11·49	17·0	8·35
30·1	14·78	26·7	13·11	23·3	11·44	16·5	8·11
30·0	14·73	26·6	13·06	23·2	11·39	16·0	7·86
29·9	14·68	26·5	13·01	23·1	11·34	15·5	7·61
29·8	14·63	26·4	12·96	23·0	11·29	15·0	7·37
29·7	14·59	26·3	12·91	22·9	11·25	14·5	7·12
29·6	14·54	26·2	12·87	22·8	11·20	14·0	6·88
29·5	14·49	26·1	12·82	22·7	11·15	13·5	6·63
29·4	14·44	26·0	12·77	22·6	11·10	13·0	6·39
29·3	14·39	25·9	12·72	22·5	11·05	12·5	6·14
29·2	14·34	25·8	12·67	22·4	11·00	12·0	5·89
29·1	14·29	25·7	12·62	22·3	10·95	11·5	5·65
29·0	14·24	25·6	12·57	22·2	10·90	11·0	5·40
28·9	14·19	25·5	12·52	22·1	10·85	10·5	5·16
28·8	14·14	25·4	12·47	22·0	10·80	10·0	4·91
28·7	14·09	25·3	12·42	21·8	10·71	9·0	4·42
28·6	14·05	25·2	12·37	21·6	10·61	8·0	3·93
28·5	14·00	25·1	12·33	21·4	10·51	7·0	3·44
28·4	13·95	25·0	12·28	21·2	10·41	6·0	2·95
28·3	13·90	24·9	12·23	21·0	10·31	5·0	2·46
28·2	13·85	24·8	12·18	20·8	10·22	4·0	1·96
28·1	13·80	24·7	12·13	20·6	10·12	3·0	1·47
28·0	13·75	24·6	12·08	20·4	10·02	2·0	0·98
27·9	13·70	24·5	12·03	20·2	9·92	1·0	0·49
27·8	13·65	24·4	11·98				

TABLE OF FEET CORRESPONDING TO DIFFERENT READINGS OF THE BAROMETER

Reading of Barometer at Sea Level assumed at 30 in. $T+t=64^\circ$

Reading of Barometer.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
29	886	796	706	617	528	439	351	263	175	87
28	1,802	1,709	1,616	1,524	1,432	1,340	1,248	1,157	1,066	976
27	2,753	2,656	2,560	2,464	2,368	2,273	2,178	2,084	1,990	1,896
26	3,739	3,638	3,539	3,439	3,340	3,241	3,143	3,045	2,947	2,850
25	4,763	4,659	4,554	4,452	4,349	4,246	4,144	4,042	3,940	3,839
24	5,830	5,721	5,613	5,505	5,398	5,291	5,185	5,079	4,973	4,868
23	6,942	6,829	6,716	6,603	6,491	6,380	6,269	6,158	6,048	5,939
22	8,103	7,985	7,867	7,749	7,632	7,516	7,400	7,285	7,170	7,056
21	9,319	9,195	9,071	8,948	8,826	8,704	8,583	8,462	8,342	8,222
20	10,593	10,463	10,333	10,204	10,076	9,948	9,821	9,695	9,569	9,443
19	11,933	11,796	11,660	11,524	11,389	11,254	11,121	10,988	10,856	10,724
18	13,346	13,201	13,057	12,914	12,771	12,630	12,489	12,349	12,210	12,071
17	14,839	14,686	14,533	14,382	14,231	14,082	13,933	13,785	13,638	13,491
16	16,423	16,260	16,098	15,937	15,778	15,619	15,461	15,304	15,148	14,993
15	18,109	17,935	17,763	17,592	17,421	17,252	17,084	16,917	16,751	16,587
14	19,911	19,725	19,541	19,357	19,175	18,995	18,815	18,637	18,460	18,284
13	21,847	21,647	21,449	21,251	21,056	20,862	20,669	20,477	20,287	20,099

TABLE SHOWING VALUES OF K (see p. 124)

T+t.	K.	T+t.	K.	T+t.	K.	T+t.	K.
Degs. F.		Degs. F.		Degs. F.		Degs. F.	
40	·973	78	1·016	116	1·058	154	1·100
42	·976	80	1·018	118	1·060	156	1·102
44	·978	82	1·020	120	1·062	158	1·104
46	·980	84	1·022	122	1·064	160	1·106
48	·982	86	1·024	124	1·067	162	1·108
50	·984	88	1·027	126	1·069	164	1·111
52	·987	90	1·029	128	1·071	166	1·113
54	·989	92	1·031	130	1·073	168	1·115
56	·991	94	1·033	132	1·076	170	1·117
58	·993	96	1·036	134	1·078	172	1·120
60	·996	98	1·038	136	1·080	174	1·122
62	·998	100	1·040	138	1·082	176	1·124
64	1·000	102	1·042	140	1·084	178	1·126
66	1·002	104	1·044	142	1·087	180	1·129
68	1·004	106	1·047	144	1·089	182	1·131
70	1·007	108	1·049	146	1·091	184	1·133
72	1·009	110	1·051	148	1·093	186	1·135
74	1·011	112	1·053	150	1·096	188	1·137
76	1·013	114	1·056	152	1·098		

REDUCTION OF BAROMETER READING TO 0° C.

Add for Temperature below 0° C. Subtract for Temperature above 0° C.

Temperature ° C.	Barometric Reading in Mm.								
	400.	450.	500.	550.	600.	650.	700.	750.	800.
0	·0	·0	·0	·0	·0	·0	·0	·0	·0
2	·1	·2	·2	·2	·2	·2	·2	·3	·3
4	·3	·3	·3	·4	·4	·4	·5	·5	·5
6	·4	·4	·5	·5	·6	·6	·7	·7	·8
8	·5	·6	·6	·7	·8	·8	·9	1·0	1·0
10	·6	·7	·8	·9	1·0	1·1	1·2	1·2	1·3
12	·7	·9	1·0	1·1	1·2	1·3	1·4	1·5	1·6

REDUCTION OF BAROMETER—*Continued*

Add for Temperature below 0° C. Subtract for Temperature above 0° C.									
Temperature C °.	Barometric Reading in Mm.								
	400.	450.	500.	550.	600.	650.	700.	750.	800.
14	·9	1·0	1·1	1·2	1·4	1·5	1·6	1·7	1·8
16	1·0	1·2	1·3	1·4	1·6	1·7	1·8	2·0	2·1
18	1·2	1·4	1·5	1·6	1·8	1·9	2·0	2·2	2·3
20	1·3	1·5	1·6	1·8	2·0	2·1	2·3	2·5	2·6
22	1·4	1·7	1·8	2·0	2·2	2·3	2·5	2·7	2·9
24	1·6	1·8	2·0	2·2	2·3	2·5	2·7	2·9	3·1
26	1·7	1·9	2·1	2·3	2·5	2·8	3·0	3·2	3·4
28	1·8	2·1	2·3	2·5	2·7	3·0	3·2	3·4	3·6
30	2·0	2·2	2·5	2·7	3·0	3·2	3·4	3·7	3·9
32	2·1	2·3	2·6	2·9	3·1	3·4	3·6	3·9	4·2
34	2·3	2·5	2·8	3·0	3·3	3·6	3·9	4·1	4·4
36	2·4	2·6	2·9	3·2	3·5	3·8	4·1	4·4	4·7
38	2·5	2·8	3·1	3·4	3·7	4·0	4·3	4·6	4·9
40	2·6	2·9	3·3	3·6	3·9	4·3	4·6	4·9	5·2

CONVERSION OF BAROMETRIC READINGS—MILLIMETRES TO INCHES

Millimetres.	Inches.	Millimetres.	Inches.	Millimetres.	Inches.	Millimetres.	Inches.
800	31·50	754	29·69	706	27·80	535	21·06
798	31·42	753	29·65	704	27·72	530	20·87
796	31·34	752	29·61	702	27·64	525	20·67
794	31·26	751	29·57	700	27·56	520	20·47
792	31·19	750	29·53	695	27·36	515	20·28
790	31·11	749	29·49	690	27·17	510	20·08
788	31·03	748	29·45	685	26·97	505	19·88
786	30·95	747	29·41	680	26·77	500	19·69
784	30·87	746	29·37	675	26·58	490	19·29
782	30·79	745	29·34	670	26·38	480	18·90
780	30·71	744	29·30	665	26·18	470	18·50
779	30·67	743	29·26	660	25·99	460	18·11
778	30·64	742	29·22	655	25·79	450	17·72

CONVERSION OF BAROMETRIC READINGS—*Continued*

Millimetres.	Inches.	Millimetres.	Inches.	Millimetres.	Inches.	Millimetres.	Inches
777	30·60	741	29·18	650	25·59	440	17·32
776	30·56	740	29·14	645	25·40	430	16·93
775	30·52	739	29·10	640	25·20	420	16·53
774	30·48	738	29·06	635	25·00	410	16·14
773	30·44	737	29·02	630	24·80	400	15·75
772	30·40	736	28·98	625	24·61	390	15·36
771	30·36	735	28·94	620	24·41	380	14·96
770	30·32	734	28·90	615	24·21	370	14·57
769	30·28	733	28·86	610	24·02	360	14·17
768	30·24	732	28·82	605	23·82	350	13·78
767	30·20	731	28·78	600	23·62	340	13·39
766	30·16	730	28·74	595	23·43	330	12·99
765	30·12	728	28·66	590	23·23	320	12·60
764	30·08	726	28·58	585	23·03	310	12·21
763	30·04	724	28·51	580	22·84	300	11·81
762	30·00	722	28·43	575	22·64	280	11·02
761	29·96	720	28·35	570	22·44	260	10·24
760	29·92	718	28·27	565	22·25	240	9·45
759	29·88	716	28·19	560	22·05	220	8·66
758	29·85	714	28·11	555	21·85	200	7·87
757	29·81	712	28·04	550	21·65	150	5·91
756	29·77	710	27·96	545	21·46	100	3·94
755	29·73	708	27·88	540	21·26	50	1·97

The Thermometer

Three scales are in use: Fahrenheit, Centigrade, and Réaumur.

Freezing point - - - - - = 32° F. = 0° C. = 0° R.

Boiling point of water at 760° mm. pressure of mercury - - - } = 212° F. = 100° C. = 80° R.

Absolute zero is −461° F., −273° C., or −218·4° R.

To convert a reading from one scale to another:—

Let F = degrees Fahrenheit,
R = degrees Réaumur,
C = degrees Centigrade.

$$\text{Then } F = \frac{9}{5}C + 32 = \frac{9}{4}R + 32 = C + R + 32.$$

$$C = \frac{5}{9}[F - 32] = \frac{5}{4}R.$$

$$R = \frac{4}{9}[F - 32] = \frac{4}{5}C.$$

CONVERSION OF DEGREES FAHRENHEIT TO DEGREES CENTIGRADE

°F	0	1	2	3	4	5	6	7	8	9
0	−17·8	−17·2	−16·7	−16·1	−15·6	−15·0	−14·4	−13·9	−13·3	−12·8
10	−12·2	−11·7	−11·1	−10·6	−10·0	−9·4	−8·9	−8·3	−7·8	−7·2
20	−6·7	−6·1	−5·6	−5·0	−4·4	−3·9	−3·3	−2·8	−2·2	−1·7
30	−1·1	−·6	·0	·6	1·1	1·7	2·2	2·8	3·3	3·9
40	4·4	5·0	5·6	6·1	6·7	7·2	7·8	8·3	8·9	9·4
50	10·0	10·6	11·1	11·7	12·2	12·8	13·3	13·9	14·4	15·0
60	15·6	16·1	16·7	17·2	17·8	18·3	18·9	19·4	20·0	20·6
70	21·1	21·7	22·2	22·8	23·3	23·9	24·4	25·0	25·6	26·1
80	26·7	27·2	27·8	28·3	28·9	29·4	30·0	30·6	31·1	31·7
90	32·2	32·8	33·3	33·9	34·4	35·0	35·6	36·1	36·7	37·2
100	37·8	38·3	38·9	39·4	40·0	40·6	41·1	41·7	42·2	42·8
110	43·3	43·9	44·4	45·0	45·6	46·1	46·7	47·2	47·8	48·3
120	48·9	49·4	50·0	50·6	51·1	51·7	52·2	52·8	53·3	53·9
130	54·4	55·0	55·6	56·1	56·7	57·2	57·8	58·3	58·9	59·4
140	60·0	60·6	61·1	61·7	62·2	62·8	63·3	63·9	64·4	65·0
150	65·6	66·1	66·7	67·2	67·8	68·3	68·9	69·4	70·0	70·6

CONVERSION OF DEGREES FAHRENHEIT TO DEGREES CENTIGRADE—*Continued*

° F.	0	1	2	3	4	5	6	7	8	9
160	71·1	71·7	72·2	72·8	73·3	73·9	74·4	75·0	75·6	76·1
170	76·7	77·2	77·8	78·3	78·9	79·4	80·0	80·6	81·1	81·7
180	82·2	82·8	83·3	83·9	84·4	85·0	85·6	86·1	86·7	87·2
190	87·8	88·3	88·9	89·4	90·0	90·6	91·1	91·7	92·2	92·8
200	93·3	93·9	94·4	95·0	95·6	96·1	96·7	97·2	97·8	98·3
210	98·9	99·4	100·0	100·6	101·1	101·7	102·2	102·8	103·3	103·9
220	104·4	105·0	105·6	106·1	106·7	107·2	107·8	108·3	108·9	109·4
230	110·0	110·6	111·1	111·7	112·2	112·8	113·3	113·9	114·4	115·0
240	115·6	116·1	116·7	117·2	117·8	118·3	118·9	119·4	120·0	120·6
250	121·1	121·7	122·2	122·8	123·3	123·9	124·4	125·0	125·6	126·1
260	126·7	127·2	127·8	128·3	128·9	129·4	130·0	130·6	131·1	131·7
270	132·2	132·8	133·3	133·9	134·4	135·0	135·6	136·1	136·7	137·2
280	137·8	138·3	138·9	139·4	140·0	140·6	141·1	141·7	142·2	142·8
290	143·3	143·9	144·4	145·0	145·6	146·1	146·7	147·2	147·8	148·3
300	148·9	149·4	150·0	150·6	151·1	151·7	152·2	152·8	153·3	153·9

CONVERSION OF DEGREES CENTIGRADE TO DEGREES FAHRENHEIT

° C.	0	1	2	3	4	5	6	7	8	9
0	32	33·8	35·6	37·4	39·2	41·0	42·8	44·6	46·4	48·2
10	50	51·8	53·6	55·4	57·2	59·0	60·8	62·6	64·4	66·2
20	68	69·8	71·6	73·4	75·2	77·0	78·8	80·6	82·4	84·2
30	86	87·8	89·6	91·4	93·2	95·0	96·8	98·6	100·4	102·2
40	104	105·8	107·6	109·4	111·2	113·0	114·8	116·6	118·4	120·2
50	122	123·8	125·6	127·4	129·2	131·0	132·8	134·6	136·4	138·2
60	140	141·8	143·6	145·4	147·2	149·0	150·8	152·6	154·4	156·2
70	158	159·8	161·6	163·4	165·2	167·0	168·8	170·6	172·4	174·2
80	176	177·8	179·6	181·4	183·2	185·0	186·8	188·6	190·4	192·2
90	194	195·8	197·6	199·4	201·2	203·0	204·8	206·6	208·4	210·2
100	212	213·8	215·6	217·4	219·2	221·0	222·8	224·6	226·4	228·2
110	230	231·8	233·6	235·4	237·2	239·0	240·8	242·6	244·4	246·2
120	248	249·8	251·6	253·4	255·2	257·0	258·8	260·6	262·4	264·2
130	266	267·8	269·6	271·4	273·2	275·0	276·8	278·6	280·4	282·2
140	284	285·8	287·6	289·4	291·2	293·0	294·8	296·6	298·4	300·2
150	302	303·8	305·6	307·4	309·2	311·0	312·8	314·6	316·4	318·2

BEHAVIOUR OF WINDS

Aviators must always be more or less at the mercy of the wind, but less as they gain experience in meeting the ever-changing wind conditions imposed upon them in practice.

Wind is air in sensible motion, and is produced by differences of pressure, which are themselves attributable to changes of temperature.

Generally, the velocity of the wind follows closely upon the temperature. Before sunrise it falls to a minimum, reaching, between 2 and 4 A.M., an almost dead calm, while between noon and 2 P.M. it rises to a maximum.

The wind is neither regular in direction nor in velocity, but blows more or less in gusts with varying currents and eddies set up by obstructions and temperature differences.

The variations of speed and of direction do not take place simultaneously, although they take place at similar intervals of time. Wilbur Wright states that a gust may come on so suddenly that the front of the machine is thrown up before the back part is acted on at all. The same authority is responsible for the statement that "it is an almost universal rule that gusts come on with a rising trend and die out with a descending trend."

These sudden variations of speed are much more marked in the presence of obstructions, and become smaller with increase of height above the ground.

Masses of air are constantly changing places, cold air descending to the earth's surface, spreading itself out, becoming warm, and then ascending in streams or currents in other places.

Ascending streams of air may be any distance apart from ¼ mile up to 20 miles, and may rise as fast as from 6 to 10 miles per hour. They are in thin sheets or long walls, and may be approximately straight or of irregular curvature. The action is continuously taking place over both sea and land, and is rendered visible in the glassy streaks or zones that are seen at sea. These calm portions are caused by the air meeting from both sides, and ascending in practically a straight line from the surface of the water. On each side of a streak the wind will be found to be blowing in opposite directions. Under some circumstances the presence of these ascending streams is made visible by the formation of cumulus clouds; it is now agreed that a cloud of this kind is merely the cap of a column of rising air. Hence care should be exercised when the sky contains a large number of isolated cumulus clouds, since there will probably be descending streams in the clear portions, and ascending ones below the clouds.

Within a thundercloud the vertical motion is very violent, and "the vertical currents are sometimes comparable with the strongest surface winds" (Dr W. N. Shaw).

The soaring of birds, a phenomenon which has hitherto been little understood, is due to the bird seeking out an ascending

stream of air which carries it upwards. Though maintaining itself at the same height above the earth's surface, it exerts little effort in doing so, and though stationary as regards the earth, it is in reality falling at some speed through the upward stream which supports it.

Over the sea the velocity of the wind is much greater than over the land. The difference is very marked between a point on the shore and a headland jutting into the sea or a lake. The average velocity of the wind in the United States all the year round at a height of 50 ft. above the ground is about 11 miles an hour (Thomas Russell).

In 1876-7 the mean of 650 daily observations over the five great oceans showed the average wind velocity to be 17 miles per hour. On land during the same period the average velocity was 12½ miles per hour.

Obstructions such as sea cliffs or the sides of quarries give rise to upward currents. Small obstructions, such as houses or groups of trees, will also start them, but at sea and on large open plains there does not appear to be any definite reason why a vertical current should commence at one place rather than at another.

Under some circumstances the wind to be expected can be predicted with a considerable degree of accuracy. An estimate of wind velocity can be got at any time between 8 A.M. and 8 P.M. in answer to a prepaid reply telegram to the Meteorological Office.

On the sea coast there is usually a light breeze from the sea in the morning, which increases towards midday, and dies to a calm in the evening. During the night the wind blows from the land in a similar fashion. These coastal winds are accompanied by opposite movements of the air in strata about 500 to 1,000 ft. high, and are rarely felt for more than 20 miles from the coast.

From the calms about the Equator to the parallel of 28° in the northern hemisphere, and to the parallel of 25° in the southern hemisphere, steady winds prevail through about two-thirds of the earth's circumference; they are known as the trade winds, and blow respectively from the north-east and the south-west.

In India the *monsoons* blow from the north-east from October to March, and from the south-west from April to September.

Within the temperate latitudes the winds are of uncertain occurrence and duration, but are more usually from the westward.

As far as England is concerned, the following rules are given by Mr W. H. Dines in a paper to the Aeronautical Society:—

"Almost every wind that blows at an inland station will be found to be stronger at a few hundred feet above the surface. As a general rule it will be found that if you face the surface wind, the wind above will come somewhat from your right hand. Suppose a balloon is at a height of 2,000 ft., an east wind is not likely to increase much in strength above this height, but a south-west or west wind is likely to do so. A south-east wind on the surface is fairly certain to turn to a south and then to a south-west wind at a moderate elevation, and a north wind may draw into a north-west, but it is not likely to do so. As a rule for winds other than north, a change

of two points of the compass in direction, and a doubling of the velocity, may be expected between the surface and 3,000 ft., excepting during a hot sunny day in spring and summer. On such days a general mixing of the air by convection currents tends to equalise the different strata, and the velocity at the surface will not be greatly less than above. At night calm mostly prevails in the lower strata if the sky is clear, and this is particularly the case on frosty nights, and even days, too, in the winter. But there is no rule hardly without an exception, and I have met with exceptions to all the above rules."

Very often an easterly or north-easterly wind may be strong near the ground, and fall off very rapidly above 800 to 1,600 ft.

The most dangerous wind met with in England is that known as the "line squall," so called because it advances with a line front like a tidal wave, usually lying S.W. and N.E., and advancing from N.W. to S.E. The signs of this wind are—

1. *A sudden fall of temperature.*
2. A veer of the wind.
3. A rise of pressure.
4. A squall of rain, hail, or snow.

The squall itself is accompanied by thunder and lightning, and must inevitably prove fatal to any aeroplane or dirigible encountered.

The above is sufficient to show that the numerous problems presented by the behaviour of the wind are of a very complex character However, the aviator is working out daily a practical solution. Though he may appear to be taking his ease while in the air, he is really responding to every trick of the wind more or less automatically, according to his degree of skill. The management of his machine becomes to him a matter of course, and his skill may be gauged by the ease with which it is accomplished.

At the first Rheims aviation meeting the majority of the competitors did not attempt to fly unless the velocity of the wind was less than 7 miles an hour. Several could start with a wind velocity of a little over 10 miles, and when started could fly in a wind of about 20 miles. At the Hendon meeting of Easter 1912 one short flight was made in a wind varying from almost nothing to 50 miles an hour, while several were made in a gusty 40-mile breeze.

Wind Force

Wind force is estimated by the Beaufort scale, which is given below. The following relations hold between the various constants:—

$$P = \cdot003V^2.$$
$$P = \cdot0105B^3.$$
$$V = 1\cdot87\sqrt{B^3}.$$

Where P = pressure on a normal plane in pounds per square foot,
V = velocity in miles per hour,
B = the Beaufort number.

These are the formulæ adopted by the Meteorological Office.

THE BEAUFORT SCALE OF WIND FORCE

Beaufort No.	General Description.	Characteristics.	Wind Force, Lbs. per Sq. Ft. Pressure on Normal Plane.	Mean Velocity.		
				Miles per Hour.	Feet per Second.	Metres per Second.
0	Calm- - -	Smoke rises vertically.	0	0	0	0
1	Light air - -	Direction of wind shown by smoke drift, but not by vanes.	·01	2	3·5	1·0
2	Slight breeze -	Wind felt on face; leaves rustle; ordinary vanes moved by wind.	·08	5	8·5	2·5
3	Gentle ,, -	Leaves and small twigs in constant motion; wind extends light flag.	·28	10	15·0	4·5
4	Moderate breeze	Raises dust and loose paper; moves small branches.	·67	15	23·0	7·0
5	Fresh breeze -	Small trees in leaf begin to sway; wavelets form on inland waters.	1·31	21	32·0	9·5
6	Strong ,, -	Large branches in motion; whistling heard in telegraph wires.	2·3	27	41·5	12·5
7	High wind -	Whole trees in motion; inconvenience in walking against wind.	3·6	35	51·5	15·7
8	Gale - - -	Breaks twigs of trees and generally impedes progress.	5·4	42	62·5	19·0
9	Strong gale -	Slight structural damage occurs; chimney pots and slates removed.	7·7	50	74·5	22·5
10	Whole ,, -	Seldom experienced inland; trees uprooted, considerable structural damage.	10·5	59	87·0	26·2
11	Storm - -	Very rarely experienced; accompanied by widespread damage.	14·0	68	102·0	31·0
12	Hurricane -	... ...	Above 17·0	Above 75	Above 110	Above 34

Storm and Wind Signals

The **South Cone** is point downwards, and is hoisted if a gale is expected from between E. and S.E., which will veer round by S. to S.W. or N.W.

The **North Cone** is point upwards, and is hoisted if gales from N.W. round by N. to N.E. or S.E. are probable.

By night a signal of lamps in the appropriate positions is hoisted. The signal is kept flying for forty-eight hours from the time the message was issued from the Meteorological Office. It may be noticed that a gale from the E. is more likely to back to the N. than to shift to the S.

Variation of Wind Velocity with Height

The wind velocity and pressure increase in the higher zones of the atmosphere, up to two or three times the surface velocity, or sometimes even more.

The following formulæ have been suggested :—

$$P=p\sqrt{\frac{H+72}{h+27}}. \quad \text{(Stevenson.)}$$

$$v=1347{\cdot}4\sqrt{\frac{H-h}{h}}. \quad \text{(Kempe.)}$$

Where P = the pressure at height H,
p = the pressure at height h,
v = the velocity at different zones.

According to Dr W. N. Shaw, a likely formula for the increase of velocity with height above the ground is—

$$V=\frac{H+a}{a}V_0.$$

Where H = height above ground at which velocity is required,
V = velocity at height H,
V_0 = velocity at ground level,
a = a constant, which may be taken as approximately equal to the height of the station above sea level.

This formula is believed to hold until the "gradient velocity," or velocity calculated from the pressure distribution, is reached; almost always lower than 3,000 ft.

To Find the Gradient Wind Velocity from the Daily Weather Chart

The "gradient" wind, as has been explained, is the wind calculated from the distribution of the isobaric lines. The velocity near the surface of the earth will be less than this, owing to friction, and depending on the nature of the ground, but the gradient wind is almost always reached before 3,000 ft., and sometimes much lower.

The table shows the distance apart of consecutive $\frac{1}{10}$-in. isobars, which under different conditions of pressure and temperature correspond to stated velocities of the gradient wind. It is calculated

for latitude 53°—that of Nottingham—but can be corrected for other latitudes by subtracting 1 per cent. from the velocity for each increase of 1° in latitude. The *direction* of the wind is along the isobaric lines, with the low pressure on the left hand, in the Northern Hemisphere.

TABLE TO FIND THE GRADIENT WIND VELOCITY FROM THE DAILY WEATHER CHART

LATITUDE 53°

Gradient Wind Velocity.		Pressure and Temperature.							Beaufort Numbers.
		In. °F.	In. °F.	In. °F.	In. °F.	In. °F.	In. °F.	In. °F.	
		31 28	31 44	31 60	31 77	… …	… …	… …	
		30 13	30 27	30 43	30 60	30 78	30 97	… …	
		… …	29 11	29 26	29 43	29 60	29 79	29 99	
		… …	… …	28 10	28 25	28 42	28 60	28 79	
Feet per Second.	Miles per Hour.	Distances Apart in Nautical Miles of Consecutive $\frac{1}{10}$-in. Isobars.							
7·3	5	520	540	560	580	600	620	640	2
14·7	10	260	270	280	290	300	310	320	3
22·0	15	170	180	190	190	200	210	210	4
29·3	20	130	140	140	140	150	150	160	5
36·7	25	100	110	110	120	120	120	130	6
44·0	30	87	90	93	97	100	100	110	
51·3	35	75	77	80	83	85	88	92	7
58·7	40	66	68	70	72	75	77	80	8
66·0	45	58	60	62	64	66	69	71	
73·3	50	52	54	56	58	60	62	64	9
80·7	55	48	49	51	53	54	56	58	10
88·0	60	44	45	47	48	50	52	54	
95·3	65	40	42	43	44	46	48	49	11
102·7	70	38	39	40	41	43	44	46	
110·0	75	35	36	37	39	40	41	43	
117·3	80	33	34	35	36	37	39	40	12
132·0	90	29	30	31	32	33	34	36	
146·7	100	26	27	28	29	30	31	32	

Correction for temperature: add to velocity 0·2 per cent. for each increase of 1° F.

Correction for pressure: add to velocity 0·33 per cent. for each decrease of 0·1 in.

WIND VELOCITY AT VARIOUS STATIONS DURING 1908

(Abstracted from a Meteorological Office Report)

Hours during which the velocity was within the given limits

Beaufort Number.	Mean Velocity, Miles per Hour.	Aberdeen.	Armagh	Brighton.	Dover.	Dublin.	Falmouth.	Fleetwood.	Glasgow.	Holyhead.	Kew.	Kingstown.
		Hours.	Hours.	Hours.	Hours.	Hours.	Hours.	Hours.	Hours.	Hours.	Hours.	Hours.
0	0	19	279	67	336	655	5	1	23	9	44	176
1	1-3	1,249	3,094	1,530	1,258	1,804	1,278	554	1,667	752	2,018	702
2	4-7	3,481	3,126	2,696	1,562	3,271	3,161	1,844	3,290	1,652	3,099	1,395
3	8-12	2,582	1,598	2,120	1,953	1,755	2,456	2,465	2,599	1,996	2,245	1,878
4	13-18	1,092	588	897	1,779	875	1,272	1,932	987	2,014	1,147	1,871
5	19-24	281	78	225	1,085	202	509	1,030	166	1,361	191	1,031
6	25-30	58	9	44	529	22	100	587	26	655	40	642
7	31-38	20	5	2	123	6	3	261	1	270	...	256
Gales 8	39-46	2	...	...	10	...	...	83	...	62	...	46
Gales 9	47-54	...	...	...	...	...	...	21	...	13	...	2
Gales 10	55-63	...	...	...	...	...	...	2	...	...	...	...
Gales 11	64-75	...	...	...	...	...	...	...	...	...	...	...
Gales 12	above 75	...	...	...	...	...	...	...	...	...	...	...
Total hours recorded		8,784	8,777	8,239	8,635	8,590	8,784	8,780	8,759	8,784	8,784	8,743
,, ,, unrecorded		...	7	545	149	194	...	4	25	...	...	41

WIND VELOCITY AT VARIOUS STATIONS DURING 1908—*Continued*

(Abstracted from a Meteorological Office Report)

Hours during which the velocity was within the given limits

Beaufort Number.	Mean Velocity, Miles per Hour.	North Shields.	Plymouth.	Pyrton Hill.	Roche's Point.	Scilly.	Shoebury-ness.	Southport.	Stony-hurst.	Valencia.	Yarmouth.
		Hours.	Hours.	Hours.	Hours.	Hours.	Hours.	Hours.	Hours.	Hours.	Hours.
0	0	22	524	315	78	82	27	17	175	93	40
1	1-3	721	916	2,934	405	344	643	355	2,643	851	743
2	4-7	2,529	1,460	2,792	1,207	1,472	1,410	1,486	3,041	1,615	2,891
3	8-12	2,995	2,279	1,512	1,853	1,855	2,858	2,647	1,869	2,401	2,712
4	13-18	1,618	1,864	408	2,114	1,913	1,867	2,179	793	2,178	1,516
5	19-24	655	983	94	1,298	1,556	935	1,067	215	1,093	530
6	25-30	112	350	9	696	813	419	665	45	410	239
7	31-38	20	70	...	209	429	76	284	3	127	96
Gales 8	39-46	1	19	...	58	153	12	74	...	16	12
Gales 9	47-54	...	6	...	9	75	...	10	...	...	...
Gales 10	55-63	...	...	...	...	6	...	...	...	...	...
Gales 11	64-75	...	...	...	...	...	...	...	...	...	...
Gales 12	above 75	...	...	...	...	...	...	...	...	...	...
Total hours recorded		8,673	8,471	8,064	7,927	8,698	8,247	8,784	8,784	8,784	8,779
,, ,, unrecorded		111	313	720	857	86	537	...	...	...	5

DIRECTION OF THE WIND IN ENGLAND

(*Based on observations by Kämtrz*)

	Percentage of Days.	Average of Days per Annum.
North - -	8·2	30·0
North-east -	11·1	40·5
East - - -	9·9	35·8
South-east -	8·1	29·9
South - -	11·1	40·5
South-west -	22·5	82·1
West - - -	17·1	62·4
North-west -	12·0	43·8
	100·0	365·0

WEATHER FORECASTS

General Indications

Valuable information is contained in the daily weather charts published by the Meteorological Office and in various newspapers. The lines of equal barometric pressure, or **isobars**, show the general distribution of atmospheric pressure, from which the probable winds can be foretold. There are two main types of distribution of the isobars, as shown in Figs. 49 and 50, and with these all other types are more or less intimately associated.

A **cyclone**, or depression, is a definite area of low pressure: usually characterised by strong winds, rough, unsettled weather, and a temperature low in summer and high in winter. The winds

blow spirally towards the low-pressure area in an anti-clockwise direction.

An **anticyclone** is a definite area of high pressure: characterised by light airs and calms, dry, hazy, or foggy weather, and a temperature high in summer and low in winter. The winds blow outwards from the high-pressure area in a clockwise direction.

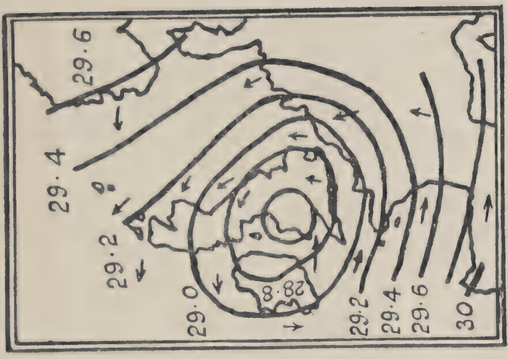


FIG. 50.—Cyclone (Bad Weather).

FIG. 49.—Anticyclone (Good Weather).

The centre of a cyclone is a general area of ascending air currents, and that of an anticyclone of descending air currents.

Local Indications

Local indications which assist in a forecast are the behaviour of the barometer and thermometer, and the aspect of the sky and clouds.

Barometer

Rapid rise - - -	Unsettled weather, liability to sudden changes.
Gradual rise - -	With a dry atmosphere, fair weather. After southerly winds, improving tendency with wind from W. or N.W.
Rise after being low -	First rising usually precedes heavy winds from the northward, continued rising indicates improving weather.
Rise after being normal	With falling temperature and dry atmosphere, wind from N.E., N., or N.W., or less wind.
Steadiness - - -	With dry atmosphere, fine weather.
Rapid fall - - -	Stormy weather and rain. If with westerly wind, storms from southward.
Considerable fall - -	High wind, rain or snow: wind from N. if thermometer is low, from S. if it is high.
Fall after being normal	With rising thermometer and increasing dampness, wind from S.E., S., or S.W. If thermometer is low, snow.
Fall - - - - -	After northerly winds, bad tendency, wind probably shifting to S. With high or increasing temperature, winds from S. or S.W., possible rain.

The barometer generally falls with a S. and rises with a N. wind: if the opposite happens the S. wind will be dry and the weather fine, or the N. wind will be strong and will bring rain. Fine weather with a low barometer is usually followed by a duration of wind or rain.

Clouds

Cirrus - - - -	Consists of flexuous fibres extending in any direction. Marestail clouds usually indicate coming wind. Average altitude, 10,000 m.
Cirro-stratus - -	A flat, widely extended cloud. A "mackerel" sky is an example. Sign of rain or snow.
Cirro-cumulus - -	Small, well-defined rounded masses in close horizontal arrangement. A forerunner of storms.

Cumulo-stratus	A mixture of the cirro-stratus and the cumulus ; may turn to nimbus, but often evaporates.
Nimbus	Usually formed from cumulo-stratus ; a dense black cloud with ragged edges, from which rain is falling.
Cumulus	Convex or conical heaps rising from horizontal base ; fair weather clouds when small, showery when large and piled up ; when very large and ragged at the top cause local thunderstorms.
Stratus	A widely extended, horizontal cloud, which increases from below. Includes some mists and fogs. Average height, 500 m.

In general, soft looking clouds accompany fine weather, and those with clear and well-defined edges presage wind. Ragged clouds and light scud are the forerunners of strong wind and rain.

Colour of Sky, etc.

Red at sunset	Fair weather.
Red at dawn	Bad weather, or wind.
Grey at dawn	Fair weather.
Bright yellow at sunset	Wind.
Pale yellow at sunset	Rain.

A high dawn (first light behind bank of clouds) foretells wind, and an unusual clearness of the atmosphere near the horizon is a very sure sign of rain.

The Chemical Weather-glass

A weather-glass which will give indications of weather changes may be made as under :—

Camphor	2 dr.
Potass. nitrate (nitre)	$\frac{1}{2}$,,
Ammon. chloride (sal-ammoniac)	$\frac{1}{2}$,,
Absolute alcohol	2 oz.
Water	2 ,,

The liquid is usually placed in a glass tube about 10 in. long by $\frac{3}{4}$ in. diameter, which must be nearly filled, and then hung so as to face north, shaded from the sun. The different appearances are as under :—

Liquid clear - - -	Bright weather.
Liquid dim - - -	Rain.
Liquid dim, with small stars in motion.	Thunderstorms.
Small dots - - -	Damp weather, with fog.
Large flakes - - -	Dull weather, snow in winter.
Crystals at bottom - -	Frost in winter.
Threads in upper portion -	Wind.
Small stars - - -	On bright days in winter, snow in one or two days.

WEATHER TABLE

The following table is given in many almanacs as indicating the kind of weather which will most probably attend the moon's entrance into any of her quarters. It must, however, be regarded as rather empirical.

Time of Moon's Entrance.	In Summer.	In Winter.
Between 12 midnight and 2 A.M.	Fair - -	Hard frost, unless wind S. or S.W.
Between 2 A.M. and 4 A.M. -	Cold with showers	Snow, and stormy.
,, 4 ,, ,, 6 ,, -	Rain - -	Stormy, with snow.
,, 6 ,, ,, 8 ,, -	Wind and rain	Stormy.
,, 8 ,, ,, 10 ,, -	Variable - -	Rain if wind W., snow if E.
,, 10 ,, ,, 12 noon -	Showery - -	Cold, and high wind.
,, 12 noon ,, 2 P.M. -	Very rainy -	Snow or wind.
,, 2 P.M. ,, 4 ,, -	Variable - -	Fair and mild.
,, 4 ,, ,, 6 ,, -	Fair - -	Fair.
,, 6 ,, ,, 8 ,, -	Fair if wind N.W., rainy if S. or S.W.	Frosty if N. or N.E., snow if S. or S.W.
,, 8 ,, ,, 10 ,, -	,,	,,
,, 10 ,, ,, 12 midnight	Fair - -	Fair, with frost.

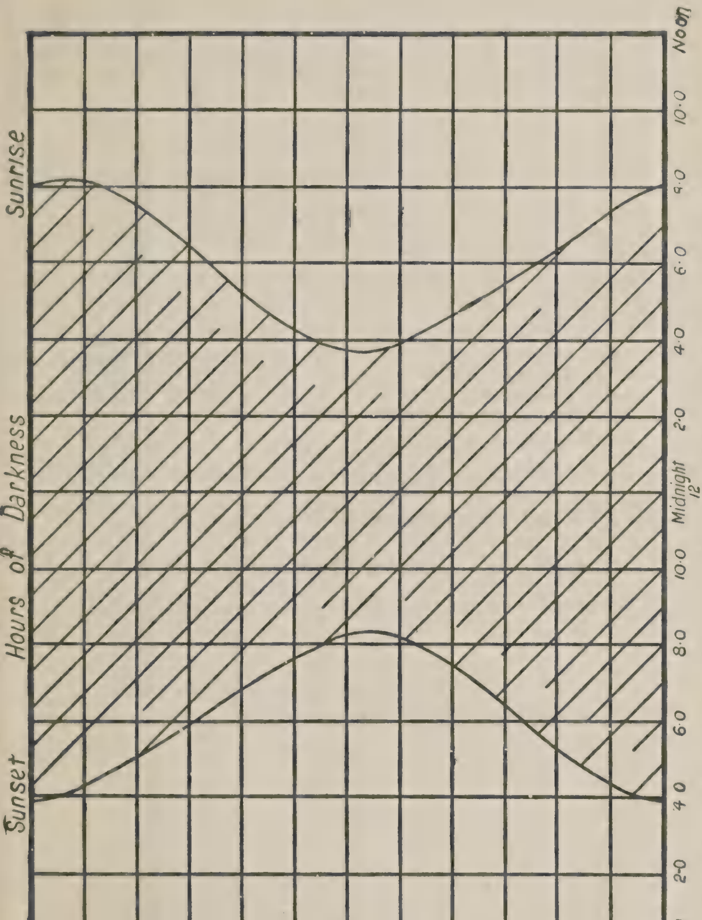


FIG. 51.—Chart showing the time of Sunset and Sunrise throughout the year.

Fig. 51 is a diagrammatic representation of the time of sunset and sunrise at Greenwich. The shaded area between the curved lines indicates the portions of each day during the year throughout which darkness prevails. One hour after sunset and one hour before sunrise are indicated by the ends of the short shading lines.

Time of Sunset

A correction has to be made to tables giving the time of sunset at Greenwich, to obtain the true time of sunset in other parts of Great Britain. The variations are as follows :—

For each degree of longitude west of London add 4 minutes, for each degree east deduct 4 minutes. In addition to this constant figure there is a variation depending upon the period of the year for places north or south of Greenwich, thus :—

March, September - - -	A slight difference only.
April, October - - -	About 2 minutes a degree.
May, November - - -	,, 4 ,, ,,
June, December - - -	,, 5 ,, ,,
July, January - - -	,, 4 ,, ,,
August, February - - -	,, 3 ,, ,,

From March to August the minutes given are to be added, and from September to February subtracted for places north of Green wich, and *vice versa* for places south of Greenwich.

Hours of Moonlight

When the moon is		4	days old, it shines till about			10 P.M.
,,	,,	5	,,	,,	,,	11 ,,
,,	,,	6	,,	,,	,,	12 ,,
,,	,,	7	,,	,,	,,	1 A.M.
,,	,,	15	days old, full moon rises about			6 P.M.
,,	,,	16	,,	,,	,,	7 ,,
,,	,,	17	,,	,,	,,	8 ,,
,,	,,	18	,,	,,	,,	10 ,,
,,	,,	19	..	..	,,	11 ,,
,,	,,	20	,,	,,	,,	12 ,,

GREENWICH

ber.	October		November.		December.		Day of Month.
S.	R.	S.	R.	S.	R.	S.	
6·46	6·2	5·37	6·56	4·32	7·46	3·53	1
6·43	6·4	5·35	6·57	4·30	7·47	3·52	2
6·41	6·6	5·33	6·59	4·28	7·49	3·51	3
6·39	6·7	5·30	7·1	4·26	7·50	3·51	4
6·37	6·9	5·28	7·3	4·25	7·51	3·50	5
6·34	6·11	5·26	7·5	4·23	7·52	3·50	6
6·32	6·12	5·23	7·6	4·21	7·54	3·50	7
6·30	6·14	5·21	7·8	4·20	7·55	3·49	8
6·28	6·16	5·19	7·10	4·18	7·56	3·49	9
6·25	6·17	5·17	7·12	4·16	7·57	3·49	10
6·23	6·19	5·15	7·13	4·15	7·58	3·49	11
6·21	6·21	5·12	7·15	4·13	7·59	3·49	12
6·18	6·22	5·10	7·17	4·12	8·0	3·49	13
6·16	6·24	5·8	7·19	4·11	8·1	3·49	14
6·14	6·26	5·6	7·20	4·9	8·2	3·49	15
6·12	6·27	5·4	7·22	4·8	8·3	3·49	16
6·9	6·29	5·2	7·24	4·6	8·4	3·49	17
6·7	6·31	5·0	7·25	4·5	8·4	3·49	18
6·5	6·33	4·57	7·27	4·4	8·4	3·50	19
6·2	6·34	4·55	7·29	4·3	8·5	3·51	20
6·0	6·36	4·53	7·30	4·2	8·5	3·51	21
5·58	6·38	4·51	7·32	4·0	8·6	3·52	22
5·55	6·40	4·49	7·34	3·59	8·6	3·52	23
5·53	6·41	4·47	7·35	3·58	8·7	3·52	24
5·51	6·43	4·45	7·37	3·57	8·7	3·53	25
5·48	6·45	4·43	7·39	3·56	8·7	3·53	26
5·46	6·47	4·41	7·40	3·55	8·7	3·54	27
5·44	6·49	4·39	7·42	3·55	8·7	3·55	28
5·42	6·50	4·37	7·43	3·54	8·8	3·56	29
5·39	6·52	4·35	7·44	3·53	8·8	3·57	30
...	6·54	4·34	...	...	8·8	3·58	31

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TABLE OF AVERAGE TIME OF SUNRISE AND SUNSET AT GREENWICH

Day of Month.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October		November.		December.		Day of Month.
	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	
1	8·8	3·59	7·41	4·47	6·47	5·38	5·37	6·30	4·34	7·20	3·50	8·5	3·49	8·18	4·25	7·47	5·14	6·46	6·2	5·37	6·56	4·32	7·46	3·53	1
2	8·8	4·0	7·39	4·49	6·45	5·39	5·35	6·32	4·32	7·22	3·50	8·6	3·50	8·18	4·27	7·45	5·16	6·43	6·4	5·35	6·57	4·30	7·47	3·52	2
3	8·8	4·1	7·38	4·51	6·43	5·41	5·33	6·34	4·30	7·23	3·49	8·7	3·50	8·17	4·28	7·44	5·17	6·41	6·6	5·33	6·59	4·28	7·49	3·51	3
4	8·8	4·3	7·36	4·52	6·41	5·43	5·30	6·35	4·28	7·25	3·48	8·8	3·51	8·17	4·30	7·42	5·19	6·39	6·7	5·30	7·1	4·26	7·50	3·51	4
5	8·8	4·4	7·34	4·54	6·39	5·45	5·28	6·37	4·26	7·27	3·48	8·9	3·52	8·16	4·31	7·40	5·20	6·37	6·9	5·28	7·3	4·25	7·51	3·50	5
6	8·7	4·5	7·33	4·56	6·36	5·47	5·26	6·39	4·25	7·28	3·47	8·10	3·53	8·16	4·33	7·38	5·22	6·34	6·11	5·26	7·5	4·23	7·52	3·50	6
7	8·7	4·6	7·31	4·58	6·34	5·48	5·24	6·41	4·23	7·30	3·46	8·10	3·54	8·15	4·35	7·37	5·24	6·32	6·12	5·23	7·6	4·21	7·54	3·50	7
8	8·6	4·7	7·29	5·0	6·31	5·50	5·22	6·42	4·21	7·31	3·46	8·11	3·55	8·15	4·36	7·35	5·25	6·30	6·14	5·21	7·8	4·20	7·55	3·49	8
9	8·6	4·9	7·27	5·2	6·30	5·52	5·19	6·44	4·19	7·33	3·46	8·12	3·56	8·14	4·38	7·33	5·27	6·28	6·16	5·19	7·10	4·18	7·56	3·49	9
10	8·5	4·10	7·26	5·3	6·27	5·54	5·17	6·45	4·18	7·35	3·45	8·13	3·57	8·13	4·39	7·31	5·28	6·25	6·17	5·17	7·12	4·16	7·57	3·49	10
11	8·5	4·11	7·24	5·5	6·25	5·55	5·16	6·47	4·16	7·36	3·45	8·14	3·58	8·13	4·41	7·29	5·30	6·23	6·19	5·15	7·13	4·15	7·58	3·49	11
12	8·4	4·13	7·22	5·7	6·23	5·57	5·13	6·49	4·15	7·38	3·45	8·14	3·59	8·12	4·42	7·27	5·32	6·21	6·21	5·12	7·15	4·13	7·59	3·49	12
13	8·3	4·14	7·20	5·9	6·21	5·59	5·10	6·50	4·13	7·39	3·44	8·15	4·0	8·11	4·44	7·25	5·33	6·18	6·22	5·10	7·17	4·12	8·0	3·49	13
14	8·2	4·16	7·18	5·11	6·18	6·0	5·8	6·52	4·11	7·40	3·44	8·16	4·1	8·10	4·45	7·23	5·35	6·16	6·24	5·8	7·19	4·11	8·1	3·49	14
15	8·2	4·18	7·16	5·13	6·16	6·2	5·6	6·54	4·10	7·42	3·44	8·16	4·2	8·9	4·47	7·21	5·36	6·14	6·26	5·6	7·20	4·9	8·2	3·49	15
16	8·1	4·19	7·13	5·14	6·14	6·4	5·4	6·55	4·8	7·44	3·44	8·17	4·3	8·8	4·49	7·19	5·38	6·12	6·27	5·4	7·22	4·8	8·3	3·49	16
17	8·0	4·21	7·12	5·16	6·12	6·5	5·2	6·57	4·7	7·45	3·44	8·17	4·4	8·7	4·50	7·17	5·40	6·9	6·29	5·2	7·24	4·6	8·4	3·49	17
18	7·59	4·22	7·10	5·18	6·9	6·7	5·0	6·59	4·6	7·47	3·44	8·17	4·6	8·6	4·52	7·16	5·41	6·7	6·31	5·0	7·25	4·5	8·4	3·49	18
19	7·58	4·24	7·8	5·20	6·7	6·9	4·59	7·0	4·4	7·48	3·44	8·18	4·7	8·5	4·53	7·14	5·43	6·5	6·33	4·57	7·27	4·4	8·4	3·50	19
20	7·57	4·25	7·6	5·22	6·5	6·10	4·55	7·2	4·3	7·49	3·44	8·18	4·8	8·4	4·55	7·12	5·44	6·2	6·34	4·55	7·29	4·3	8·5	3·51	20
21	7·56	4·27	7·4	5·23	6·2	6·12	4·53	7·4	4·2	7·51	3·44	8·18	4·10	8·2	4·57	7·9	5·46	6·0	6·36	4·53	7·30	4·2	8·5	3·51	21
22	7·54	4·29	7·2	5·25	6·0	6·14	4·51	7·5	4·1	7·52	3·45	8·18	4·11	8·1	4·58	7·7	5·48	5·58	6·38	4·51	7·32	4·0	8·6	3·52	22
23	7·53	4·31	7·0	5·27	5·57	6·16	4·49	7·7	3·59	7·54	3·45	8·19	4·12	8·0	5·0	7·5	5·49	5·55	6·40	4·49	7·34	3·59	8·6	3·52	23
24	7·52	4·33	6·58	5·29	5·56	6·17	4·47	7·9	3·58	7·55	3·45	8·19	4·14	7·59	5·1	7·3	5·51	5·53	6·41	4·47	7·35	3·58	8·7	3·52	24
25	7·51	4·34	6·56	5·31	5·53	6·19	4·45	7·10	3·57	7·56	3·46	8·19	4·15	7·57	5·3	7·1	5·53	5·51	6·43	4·45	7·37	3·57	8·7	3·53	25
26	7·49	4·36	6·54	5·32	5·51	6·21	4·43	7·12	3·56	7·57	3·46	8·19	4·16	7·56	5·5	6·59	5·54	5·48	6·45	4·43	7·39	3·56	8·7	3·53	26
27	7·48	4·38	6·51	5·34	5·49	6·22	4·41	7·14	3·55	7·59	3·47	8·19	4·18	7·54	5·6	6·57	5·56	5·46	6·47	4·41	7·40	3·55	8·7	3·54	27
28	7·47	4·40	6·49	5·36	5·46	6·24	4·39	7·15	3·54	8·0	3·47	8·19	4·19	7·53	5·8	6·54	5·57	5·44	6·49	4·39	7·42	3·55	8·7	3·55	28
29	7·45	4·41	6·48	5·37	5·44	6·26	4·37	7·17	3·53	8·1	3·48	8·19	4·21	7·52	5·9	6·52	5·59	5·42	6·50	4·37	7·43	3·54	8·8	3·56	29
30	7·44	4·43	...	...	5·42	6·27	4·36	7·19	3·52	8·2	3·48	8·18	4·22	7·50	5·11	6·50	6·1	5·39	6·52	4·35	7·44	3·53	8·8	3·57	30
31	7·42	4·45	...	...	5·40	6·29	...	...	3·51	8·3	...	...	4·24	7·48	5·12	6·48	...	...	6·54	4·34	...	...	8·8	3·58	31

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DIVISION VIII

MILITARY INFORMATION AND SIGNALLING

MILITARY INFORMATION

It seems probable that the chief use of the aeroplane in war will be for purposes of reconnaissance. The following articles of International Law have a bearing on the use of military aeroplanes :—

St Petersburg, 1868.—The following Powers bound themselves not to use in war any projectile of less weight than 14 oz. which is explosive or charged with fulminating or inflammable substances—Austria-Hungary, Belgium, Brazil, Denmark, France, Germany, Great Britain, Greece, Italy, Holland, Norway, Persia, Portugal, Russia, Sweden, Switzerland, Turkey.

Hague Convention, 1899.—Attack or bombardment of undefended localities is forbidden. Notice of bombardment, except in cases of assault, should be given if it is possible. Buildings devoted to religion, art, science, and charity, and hospitals, provided they are not at the same time used for military purposes, should be spared as far as possible.

Soldiers not in disguise, soldiers or civilians carrying despatches openly, and *balloonists with despatches or maintaining communication between parts of an army or territory*, are not spies.

In the case of a hostile occupation of any territory, property of companies and private persons, such as railways, telegraphs, ships, arms, war material, etc., may be taken possession of and used, but must be restored at peace, and indemnities paid.

The Hague Convention of 1899 also prohibited the use of projectiles, the sole object of which is the diffusion of asphyxiating or harmful gases; also, for a term of five years, the throwing of explosives or projectiles from balloons. Great Britain dissented from both these provisions, and the United States from the latter one.

The Hague Convention of 1907 confirmed the prohibition of bombardment, *by any means whatever*, of undefended towns, villages, dwellings, or buildings. The provision as to the throwing of projectiles from balloons was not ratified, except by the United States.

It will be seen that bombardment from land, sea, or air may only be used against fortified places or areas occupied by troops.

The problem of dropping any considerable weight from an aeroplane with safety to the pilot and certainty of aim while the machine is high enough to be out of range, cannot yet be regarded as solved; but under cover of darkness there is no need to keep at a great height, and undoubtedly severe damage could be done to hostile arsenals and headquarters. In the case of a dirigible, the release of 1 per cent. of its weight would cause an ascent of about 260 ft.

For reconnaissance and similar duties the field of the aeroplane seems almost unlimited. General Roques, lately in charge of French military aeronautics, has given it as his opinion that "Aeroplanes carrying a steersman, an observer, and a combatant, will eventually supersede cavalry for scouting purposes."

The important news to be obtained before an engagement is the movement of hostile troops, etc.; the aeroplane is particularly fitted for this "strategical" reconnaissance, which will usually involve comparatively long journeys. The radius of observation at a height of 4,000 or 5,000 ft. is about 5 miles.

For troops moving along a road the following gives the approximate number passing a given point per minute:—

Infantry in fours - - - - - - -	200
Cavalry in sections, walking - - - -	120
,, ,, trotting - - - -	250

In dusty weather, the form of cloud raised by troops is a guide to their composition: that raised by cavalry is high and light, that by infantry or wagons is lower and denser.

The collection of information during an engagement is much more dangerous, and is not so easy for a high-speed machine. It is possible that better results will sometimes be obtained from kites or captive balloons, since they are able to remain stationary while the observations are made. It is stated that a captive balloon may ascend for an extended reconnaissance 3 miles from the hostile artillery, and for a short observation close to the most advanced troops; the latter case is more within the sphere of usefulness of the aeroplane. Good observations of artillery fire can be made from 7,000 yds., or more in the case of heavy artillery. The military type of captive balloon can be unpacked and filled and an ascent made within half an hour, and is easily transported when packed.

The following points should be clearly understood by the scout before the start:—

1. The special information that is required.
2. In which directions and to what distance he is required to go.
3. The method of reporting any intelligence if he is unable to return.
4. What is known of the disposition of the enemy's troops, and the disposition of his own troops and their probable movements, within his sphere of observation.

Military authorities insist upon the importance of as complete a knowledge as possible of the disposition of his own troops by the

general officer commanding-in-chief; it is very likely that this personal reconnaissance will be made by air in the future.

In writing a report the following points may be noticed :—

Clearness and conciseness are the first requisites. Dates and times should always be given where possible; the hour of 12 should be specified as "noon" or "midnight," and a night referred to by the date of the day before and after, as "night 1st-2nd April." Names should be printed in capitals to avoid misunderstanding. A convenient method of identifying a spot on the map, if the same one is in use by the receiver of the message, is by referring it to the position of a letter in a prominent place-name, thus: "1 mile S. of the B in SALISBURY." Reports should begin with the full designation of the officer to whom they are addressed, and end with that of the sender and the exact time and mode of despatch.

The following probable uses of the aeroplane in warfare have been given by different authorities :—

1. Reconnaissance.
2. Destruction of supplies, etc.
3. Dispatching instructions at high speed.
4. Assisting the general officer commanding-in-chief to control his troops during an engagement.
5. To reach points otherwise inaccessible.
6. To carry high officials to points where their personality is needed.

During the discussion on the military aeroplane held at the Aeronautical Society at the end of 1911, it was generally agreed that military aeroplanes would come under two main types: (1) a single-seater high-speed machine for extended strategical reconnaissance, capable of quick climbing, silent, and probably of light construction; (2) a slower speed machine to carry two or perhaps three men, to be used for "destroying" purposes and for tactical reconnaissance, fitted with a strong landing chassis, dual control, and some form of shooting apparatus. A steady machine is required for this purpose to give a good gun-platform. Standardisation and simplicity of construction are most important in both types, while the observer must be so placed as to have a good radius of vision.

In order to give some idea of the requirements of a military pilot, the following list of things practised by the English officers of the Air Battalion during the summer of 1911 may be interesting :—

Quick rising.
Passenger carrying.
Landing on unknown ground.
Flying by compass.
Testing instruments.
Observation of country.
Aerial reconnaissance.
Writing reports.
Flying in fog and clouds.
Pegging out machine at night.
Assembling and dismounting machines.
Repairs.
Preparing for transport by rail or car.
Bomb dropping and dropping messages.
Speed trials.
Engine tests.

In sketch maps the following conventional signs used in the British Army will be useful :—

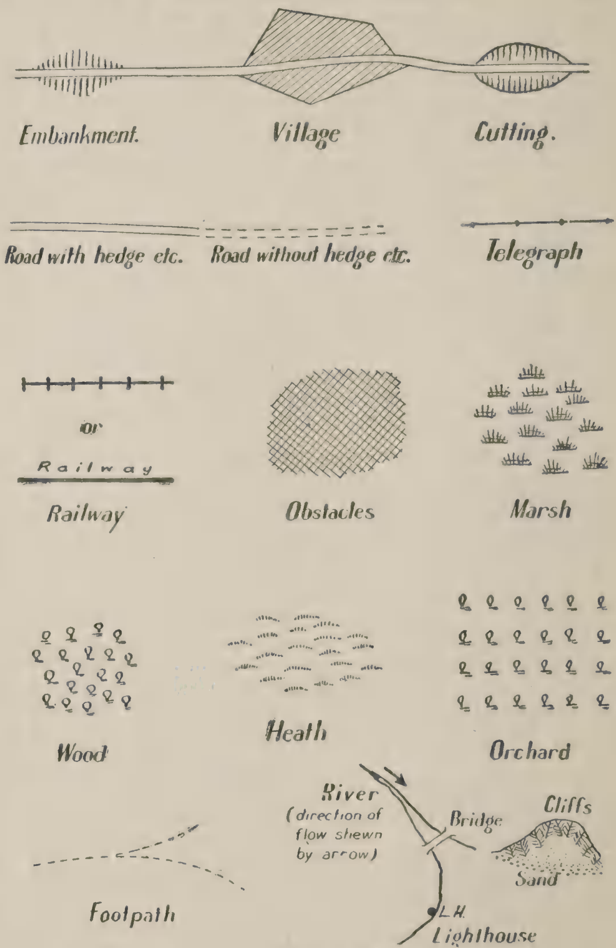

FIG. 52.—Conventional Signs used in Field Sketching.

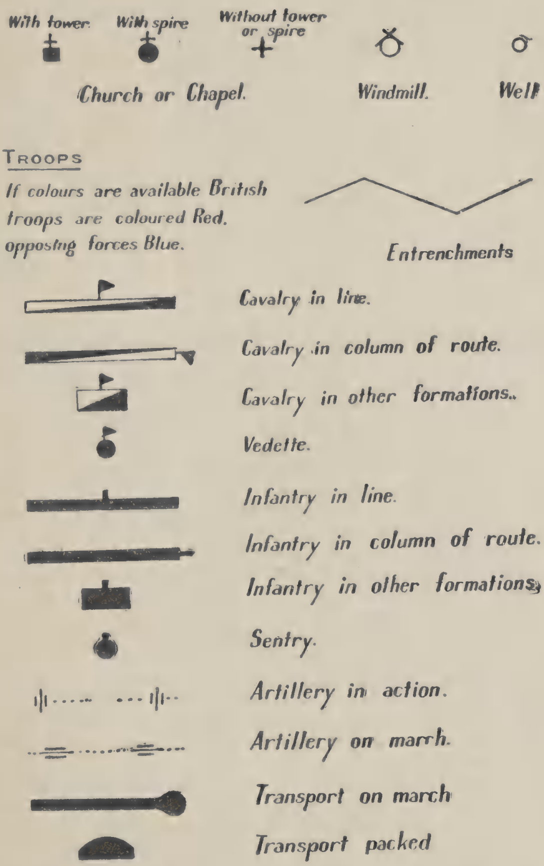

FIG. 53.—Conventional Signs used in Field Sketching.

Artillery, etc.

APPROXIMATE RANGES OF FOREIGN ARTILLERY IN YARDS

	Horse Artillery.	Field Artillery.	Field Howitzers.	Heavy Artillery.
France - - -	7,700	9,000	6,200	7,000
Germany - -	6,600	6,600	6,450	6,600
Austria - - -	7,000	7,000	6,600	...
Italy - - -	6,000	6,000	...	...
Russia - - -	4,480	6,000	3,600	9,500
United States -	7,500	7,500	4,500	5,000

Most foreign rifles are sighted up to 2,187 yds.; the Lee-Enfield to 2,800 yds.

The average width over which a shrapnel shell is effective is about 25 yds. The limit of the forward effect from the point of bursting at effective range is about 200 yds. The radius of the explosion of a high explosive shell is about 25 yds.

For other than special ordnance, 9,000 ft. high is safe to be out of range.

The development of special artillery is, however, proceeding rapidly: it is reported that a new one-pounder produced by the United States, and tested at Indian Head, showed accurate shooting up to a height of 10,000 ft., with an angle of elevation of 85°. A six-pounder has also been tested, and is said to have a maximum range of 7 miles.

The German firm of Krupp manufacture three distinct types of gun for use against aeroplanes. The smallest one has a bore of 6·5 cm. (2·56 in.) and a length of 35 calibres; it fires a shell weighing 4 kg., or 8·8 lbs. The muzzle velocity of the shell is 2,030 ft. per second, the extreme range 9,450 yds., and the greatest height that can be reached 18,700 ft. The gun can be elevated to an angle of 70°.

The next size has a bore of 7·5 cm. (2·95 in.) and a length of 35 calibres; the shell weighs 5½ kg., or 12 lbs. 2 oz. The muzzle velocity is 625 m. per second (2,050 ft. per second), the extreme range 9,100 m. (10,280 yds.), and the extreme height 6,300 m. (20,670 ft.). This gun can be elevated to 75°, and is mounted on a motor car, which carries a stock of sixty-two shells.

The largest size is intended for naval use, and has a bore of 10·5 cm. (4·14 in.), with a length of 35 calibres. Muzzle velocity 700 m. per second (2,300 ft. per second), maximum range 13,500 m.

(14,770 yds.), greatest height 11,400 m. (37,400 ft.). Elevation to 75°.

A 5-cm. gun for use against aircraft is made by the Rheinische Metallwaarken und Maschinenfabrik, of Dusseldorf. It has a length of 30 calibres, and an elevation of 70° above the horizontal.

A 3-in. gun used in the 1910 French manœuvres had a 3-mile range and an elevation of 66°: the shells exploded at a maximum height of 7,200 ft.

Special shells are also manufactured by Krupps: since there is difficulty in observing the error of aiming with the ordinary shell, the special type leave a trail of dense smoke behind them, and thus allow the trajectory to be clearly seen and corrected. A slightly different form is made by the Dusseldorf firm mentioned above: in this type the ordinary shrapnel contains a second explosive shell, which goes on after the explosion of the shrapnel, giving out a smoke trail.

SIGNALLING

A knowledge of signalling will be very useful to the aeroplane scout. The following outline is intended as a guide to the civilian who wishes to become conversant with this means of communication. The methods in use in the Army all depend on either the semaphore or the Morse alphabet.

These alphabets are as follows:—

SEMAPHORE ALPHABET

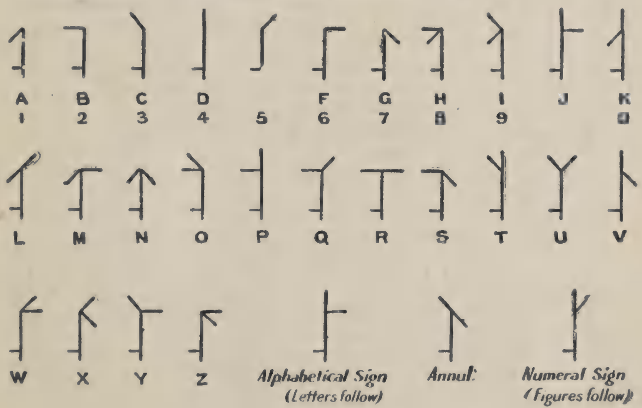

Fig. 54.

The small arm on the left of the post is the "indicator," and is used to show from which side the signals are to be read. In the foregoing alphabet the signaller and the reader are facing each other. When sufficient practice has been obtained the signals can be read with equal clearness whether the signaller has his back to or is facing the reader. Figures are distinguished by being preceded by the "numeral sign" and followed by the "alphabetical sign." They are checked by being repeated back from the reader to the signaller.

MORSE INTERNATIONAL CODE

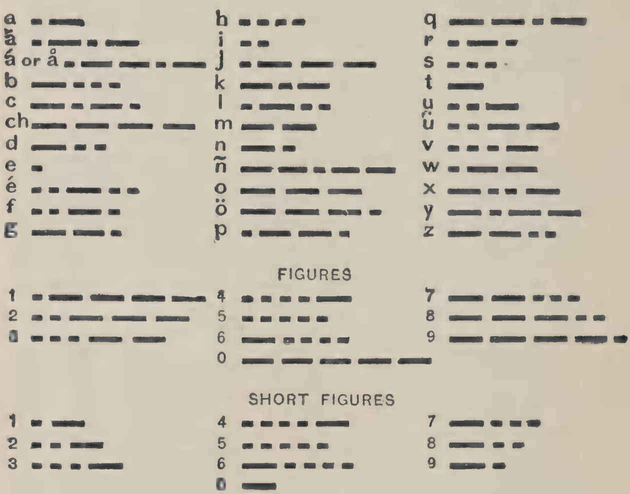

Fig. 55.

SPACING AND LENGTH OF SIGNALS

(1) A bar is equal to three dots; (2) the space between the signals which form the same letter is equal to one dot; (3) the space between two letters is equal to three dots; (4) the space between two words is equal to five dots.

The two sets of numerals given are used under different circumstances. In ordinary Army signalling "short numerals" are used, while in wireless and ordinary telegraphy, and in communication between the Navy and Army, use is made of the "long numerals," except when transmitting a code message all in figures, or in re-

petition. When the "short numerals" are being used, the letters F I (figures intended) are sent before a group of figures is signalled, and the letters F F (figures finished) when the group is finished. This is to prevent confusion between the short numerals and the letters of the alphabet, since some of the symbols are similar. To

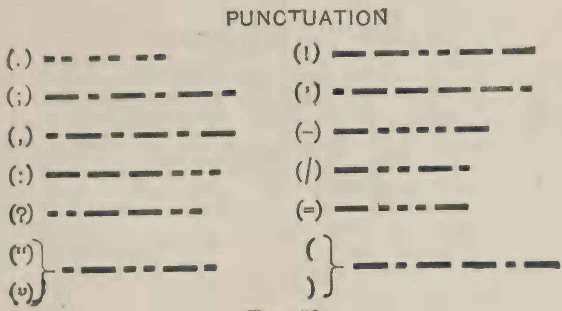

FIG. 56.

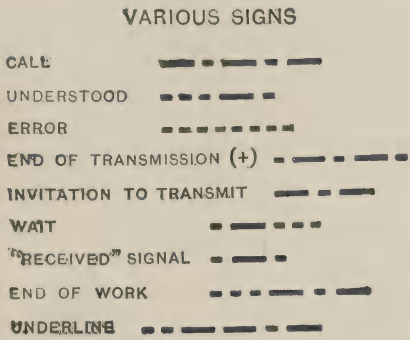

FIG. 57.

check over a group of figures, the reader signals back the corresponding letters of the alphabet, omitting J, as follows :—

A	is signalled	back	to check	1	F	is signalled	back	to check	6
B	,,	,,	,,	2	G	,,	,,	,,	7
C	,,	,,	,,	3	H	,,	,,	,,	8
D	,,	,,	,,	4	I	,,	,,	,,	9
E	,,	,,	,,	5	K	,,	,,	,,	0

For short distances a **semaphore** is used, the signaller's arms being used to form the letters : a conspicuous object, such as a handkerchief or small flag, may be held in each hand : the parties in communication always face each other if it is possible. To call another station "J" is signalled, the arms being waved : the answer is "J." "Repeat" is signalled "R."

WIRELESS TELEGRAPHY

Some of the larger and more powerful seaplanes are now equipped with wireless telegraphic apparatus. The necessary aerial usually consists of a trailing wire. Air-ships are similarly equipped. This method of signalling is, of course, much more effective than the dropping of smoke balls and tinsel, except, of course, for gun firing range indications.

DIVISION IX

AERO CLUBS AND SOCIETIES

FÉDÉRATION AÉRONAUTIQUE INTERNATIONALE

Headquarters.—35 Rue François 1er, Paris.

President.—S.A.I. Prince Roland Bonaparte (France).

Vice-Presidents.—

Baron Economo (Austria).
Fernand Jacobs (Belgium).
Comte Henry de la Vaulx (France).
Generalleutnant Freiherr von der Goltz (Germany).
Roger W. Wallace, K.C. (Great Britain).
Deputy Montu (Italy).
Cortlandt F. Bishop (U.S.A.).

Secretary.—Paul Tissandier (France).

Reporting Secretary.—Sredinsky (Russia).

Treasurer.—Ernest Zens (France).

Clubs Affiliated to the International Aeronautical Federation

America.—Aero Club of America, 297 Madison Avenue, New York City, U.S.A.

Argentine Republic.—Aero Club Argentino, 460 Avenida de Mayo, Buenos-Aires.

Austria.—Osterreichischer Aero Club, Tuchlauben, 3, Vienna.

Australia.—Aerial League of Australia,* *Hon. Sec.*, Capt. George A. Taylor, 17 Grosvenor Street, Sydney, N.S.W.

Belgium.—Aéro Club de Belgique, [illegible] Avenue Marnix, Brussels.

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DIVISION X

GLOSSARY OF TERMS USED IN FLYING

Aero.—Appertaining to the air.

Aerocurve.—Any curved supporting surface. An aerofoil.

Aerodone.—A gliding or soaring appliance which is not self-propelled.

Aerodonetics.—The science of gliding and soaring apparatus.

Aerodrome.—The popular name given to a ground used for the practice of flight. Really this would mean an "air runner" or flying machine of any kind. Sometimes used to describe power-propelled flying appliances only.

Aerodromics.—The science of flying appliances. [In this word Lanchester includes aerodynamics and aerodonetics.]

Aerodynamics.—The science relating to the effects produced by air in motion.

Aerofoil.—A cambered supporting surface of stream-line form.

Aerometer.—An instrument for determining the density of the atmosphere.

Aeronat.—An airship or dirigible balloon.

Aeronaut.—The pilot of a balloon.

Aeronautics.—The entire science of aerial navigation.

Aeronef.—Any self-propelled steerable aerial appliance.

Aeroplane.—A heavier-than-air flying machine, dynamically supported by the reaction of the air upon fixed planes.

Aerostat.—An appliance which is sustained in the air through the medium of a gas lighter than air. The gas-bag itself.

Aerostatics.—The science relating to the effects produced by buoyancy in air by means of displacement. The study of the mechanical effects produced by air at rest.

Aerostation.—The navigation of the air by lighter-than-air machines, dirigibles, or balloons.

Ailerons.—Balancing planes placed at the lateral extremities of the main deck of an aeroplane, or between the decks of a biplane. Flexible extensions to the trailing edge of the main deck at its extremities, which can be operated to maintain lateral stability.

Ailes.—Wings.

Air Pocket.—A local condition of the air which causes an aeroplane to drop suddenly; either a downward current, or a local following gust.

Airship.—A dirigible balloon or aeronat.

Anemometer.—An instrument for measuring the speed of the wind.

Angle of Deflection.—The effective angle of an aerofoil for imparting a downward velocity to the air engaged. Equal to the sum of the angles of incidence and of trail.

Angle of Entry.—The angle that the front edge of an aerofoil makes with the chord.

Angle of Incidence or Inclination.—The angle between the horizontal and the chord, that is, the angle at which an aerofoil is tilted.

Angle of Trail.—The angle made between the trailing edge and the chord.

Apteroid Aspect.—The converse of pterygoid aspect, *i.e.*, with the greater dimension arranged in the direction of flight. End-on aspect.

Arched.—Curved as viewed from the front (of an aerofoil).

Aspect Ratio.—The ratio of the length of the span to the width of the chord. When this ratio is greater than unity the planes are in pterygoid, or broadside aspect. When less than unity they are said to be in apteroid or end-on aspect. In modern machines the broadside aspect is usually employed, the aspect ratio being about 5.

Atterrissage.—The landing or descent.

Attitude.—The angle made by the longitudinal axis of an aeroplane with its line of flight.

Aviation.—The art of flying as distinct from ballooning.

Aviator.—The pilot or driver of an aeroplane.

Aviplane.—A flying machine which imitates the movements of a bird.

Balancing Planes or Balancers.—Flexible extensions, auxiliary planes, or balancing tips used for the purpose of maintaining lateral stability.

Ballonnet.—An inner balloon filled with air under slight pressure, so as to make the outer envelope of a dirigible maintain its shape.

Biplane.—Flying machine, the general feature of whose construction is two superposed parallel decks, planes, or supporting surfaces.

Booms.—The main longitudinal portions of a girder.

Broadside Aspect.—Having the lesser dimension of the planes in the direction of flight.

Buoyancy.—The property by which a balloon remains floating in the air.

Cabane.—The "shelter" formed on a monoplane by the mast to which the wings are stayed.

Camber.—The maximum depth of curvature of a deck or plane. The versine of the arc subtended by the chord.

Cant.—To elevate or depress one side of an aeroplane.

Cellule.—The box-like rectangular compartment formed by planes and panels or curtains set horizontally and vertically.

Centre of Effort.—The point at which a force spread over an area may be considered as concentrated, *e.g.*, the centre of effort of a propeller lies in its axis.

Chassis.—The framework or carriage upon which the aeroplane rests.

Chord.—The distance between the leading and trailing edges of the plane.

Cloisonné.—Of cellular construction (applied to a biplane).

Cross-tail.—A tail formed by intersecting vertical and horizontal planes.

Curtains.—The vertical panels or planes placed between the decks of a biplane or the tail thereof, so as to give it a cellular or box-like construction, as in the Voisin biplane.

Deck.—A single or double surfaced plane of a flying machine. A more correct term than plane since this portion of the apparatus is always cambered or curved.

Dihedral Angle.—The angle made by the wings of an aeroplane at their junction with each other.

Dirigible.—Power-driven steerable balloon.

Drift.—The component of the force due to air resistance on an inclined plane or aerofoil in the direction of the air current, or of the motion through the air.

Double-surfaced (of an aeroplane deck).—Having the upper and lower surfaces made of two distinct layers of fabric, between which lie the spars and ribs of the plane.

Elevator.—The adjustable horizontal plane or planes for directing and controlling an aeroplane vertically.

Empennage.—A non-lifting tail, *q.v.*

Entering Edge.—The front edge of an aerofoil or the deck of an aeroplane.

Envelope.—The covering of the gas-containing part of a balloon.

Envergue.—The distance from tip to tip of the main plane. The span.

Envole.—Flight.

Equilibrator.—The tail of an aeroplane.

Equilibrium.—In connection with aeroplanes this word is used in the same sense as stability; for balloons it means the keeping at an uniform altitude.

Equipoise.—Equilibrium, the two sides balanced.

Fin.—A vertical plane set above the back of an aeroplane in a longitudinal position.

Fore-and-aft Control.—The system of interconnecting leading and rear elevators.

Fusiform.—Shaped like a spindle.

Fuselage.—The outrigger or framework connecting the main planes with the tail-piece or with the elevator.

Gaining Pitch.—A propeller is said to have a gaining pitch when the angle of the blade to the axis at any section increases from front to back; intended to deflect the air without shock, on the same principle as the camber of an aerofoil.

Gap.—The vertical distance between the decks of biplanes and multiplanes, usually equal in dimension to the chord.

Gauchissement.—The method used by the Wrights for warping the ends of the principal planes in order to preserve lateral equilibrium, in this way doing without balancing planes or ailerons.

Girder.—A structural member intended to resist bending, and built up so as to combine strength and lightness.

Glider.—An aerodone, a gliding or soaring appliance which is not self-propelling.

Gliding Angle.—The angle to the horizontal at which a flying machine descends when not propelled by an engine. The ratio of the height of glide to length of glide.

Guy Wires.—Same as "stays," *q.v.*

Gyroplane.—A flying machine with revolving wings. A helicopter.

Hangar.—A shed for housing aeroplanes or balloons.

Head Resistance.—The product of the gliding angle and the weight of an aeroplane (with pilot, etc.),

or $$\frac{\text{height of glide}}{\text{length of glide}} \times \text{weight.}$$

Helical.—Spiral or screw like.

Hélice.—A propeller or screw.

Helicopter.—A flying machine whose lift is obtained by propellers on approximately vertical shafts. A vertical propeller.

Helix.—The trace of a point moving uniformly round a cylinder at the same time ascending at a uniform rate.

Ichthyoid.—Fish shaped. A body having a practical stream line form in viscous fluids.

Keel.—A vertical plane arranged longitudinally under a flying machine.

Length.—When used of an aeroplane, the fore-and-aft dimension.

Lift.—The component of the force due to air resistance on an inclined plane or aerofoil, perpendicular to the direction of the air current, or of the motion through the air. The upward or lifting force of an aeroplane.

Lifting Tail.—A tail in which the horizontal plane is set to carry a proportion of the weight of the aeroplane.

Loading.—The weight carried per square foot of sustaining area.

Longeron.—A longitudinal member of the chassis.

Magneto.—A dynamo with permanent steel magnets used for firing the mixture in a petrol engine cylinder.

Monoplane.—A flying machine in which the main supporting surface consists of a single plane.

Multicellular.—A flying apparatus with many planes of cellular construction.

Multiplane.—A flying machine having more than two parallel planes or supporting surfaces.

Nacelle.—The car of a balloon or dirigible. An enclosed shelter for the pilot of a biplane.

Non-Lifting Tail.—A tail in which the horizontal plane is set practically edge-on to the direction of motion, so that it carries none of the weight of the machine.

Non-Rigid.—A term applied to a dirigible balloon whose envelope is not built on a stiff framework.

Normal.—Perpendicular to the direction of flight or of an air current.

Ornithopter.—A flapping wing flying machine intended to imitate a bird.

Orthopter.—A flapping wing flying machine.

Outrigger.—The fuselage or framework connecting the main planes with the tail-piece or the prow.

Panel.—A vertical curtain placed between the decks of a biplane.

Panne.—A breakdown.

Patins.—The skids which bear the brunt of the shock in the case of the violent landing of a flying machine.

Piste.—Racing track or course.

Plane.—The term applied to the supporting surfaces of a flying machine. In this respect it is not quite accurate, as these surfaces are never flat, but cambered, and therefore more correctly described as decks.

Pocket.—That part of the fabric used to enclose the main transverse spars of a single surface deck. Pockets are employed in order that sharp angles may be avoided.

Propeller.—The screw for driving an aeroplane, placed behind the main planes, as opposed to a "tractor," placed before them.

Prow.—A vertical plane fixed in the front of a flying machine to improve the control of the vertical rudder.

Pterygoid Aspect.—Wing-like aspect. The converse of apteroid aspect, *i.e.*, with the lesser dimension in the direction of flight, as in the wing plan-form of a bird. Broadside aspect.

Pylons.—The "mark towers" used to define the course for an aeroplane contest.

Pylon or Starting Pylon.—The derrick used to give the initial impetus to a flying machine which is not provided with wheels for running over the ground; or the mast to which the wings are stayed on a monoplane.

Radiator.—A vessel having a large cooling surface, for cooling the jacket water of a petrol engine.

Remou.—A local eddy in the air.

Ribs.—The members used to give strength and shape to the deck of a flying machine in a fore and aft direction.

Righting Tips.—Balancers attached to the lateral extremities of the deck of an aeroplane.

Rigid.—A term applied to a dirigible balloon whose envelope is provided with a stiff framework to keep it in shape.

Rudder.—The vertical plane or planes of a flying machine, used in conjunction with the balancers for steering the machine to the right or the left.

Semi-rigid.—A term applied to a dirigible balloon which maintains its shape partly by the assistance of a suitable framework.

Skids.—The part of the chassis which bears the brunt of the shock in the case of the violent landing of a flying machine.

Soaring.—Gliding in a rising current of air.

Span.—The transverse dimension of an aeroplane.

Spars.—The main transverse portions of the framework of the decks of a flying machine.

Spread.—Same as "span."

Stabilisers or Stabilisators.—Balancing planes or ailerons at the ends of the main planes of a flying machine for the purpose of maintaining lateral stability. A tail.

Stability.—The maintenance of even flight. Absence of rolling, pitching, or swerving.

Stepped.—The arrangement of the decks of an aeroplane in tandem and at different levels (arranged like a flight of stairs).

Straight Pitch.—A propeller is popularly said to have a "straight pitch" when its blades are set at the same angle to the axis throughout their length.

Struts.—The main supporting members between the decks of a biplane. Any members intended to resist compression.

Sustainers.—The main planes.

Sweep.—The vertical distance within which the air is given a downward velocity by the horizontal passage of an aerofoil. It is sometimes assumed to be equal to the chord.

Swerve.—The movement of an aeroplane about an approximately vertical axis; a loss of stability about a similar axis.

Tail.—A plane, or group of planes, which may include both vertical and horizontal planes, carried behind the main decks of a flying machine to assist in maintaining the balance of the machine in the direction in which it is travelling; usually contains the rudder and often the elevator.

Tandem.—Having the main planes so arranged that they do not overlap in plan.

Ties.—The wires or other material employed for tieing or holding the various parts of a flying machine together where the strain comes.

Tilt.—An elevation or depression of the front of an aeroplane or aerofoil.

Tractor Screw.—A screw in front of an aeroplane.

Triplane.—A flying machine with three superimposed decks or planes.

Virage.—A turn or curve.

Vol Plané.—A glide to earth with the engine stopped.

Wake—Wash.—The downward stream of air produced by the passage of an aeroplane; the backward stream of air from a propeller.

Warping.—The system of bending down or up the ends of the principal planes of an aeroplane in order to preserve lateral equilibrium.

Webs.—The stiffening ribs for a double surfaced deck.

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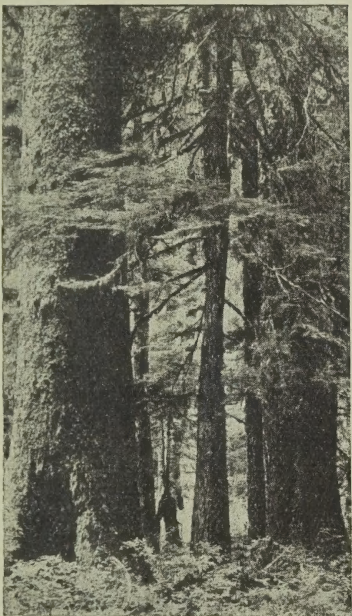

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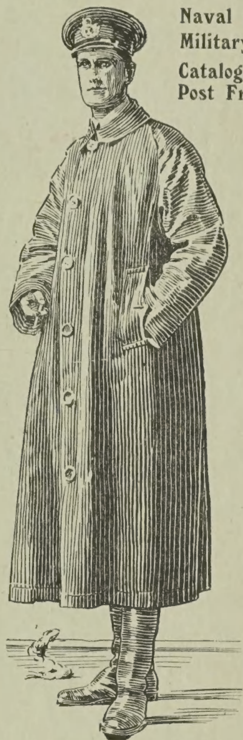

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